United States Patent [19]

Harrison, III et al.

[11] **3,747,087**

[45] **July 17, 1973**

[54] **DIGITALLY CONTROLLED COMPUTER ANIMATION GENERATING SYSTEM**

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[22] Filed: **June 25, 1971**

[21] Appl. No.: **156,762**

[52] **U.S. Cl.** ...... **340/324 AD,** 178/6.8, 178/DIG. 6, 315/19

[51] **Int. Cl.** **G06f 3/14**

[58] **Field of Search** .... 340/324 A, 324 AD; 315/19, 24; 178/6.8, DIG. 6, DIG. 35

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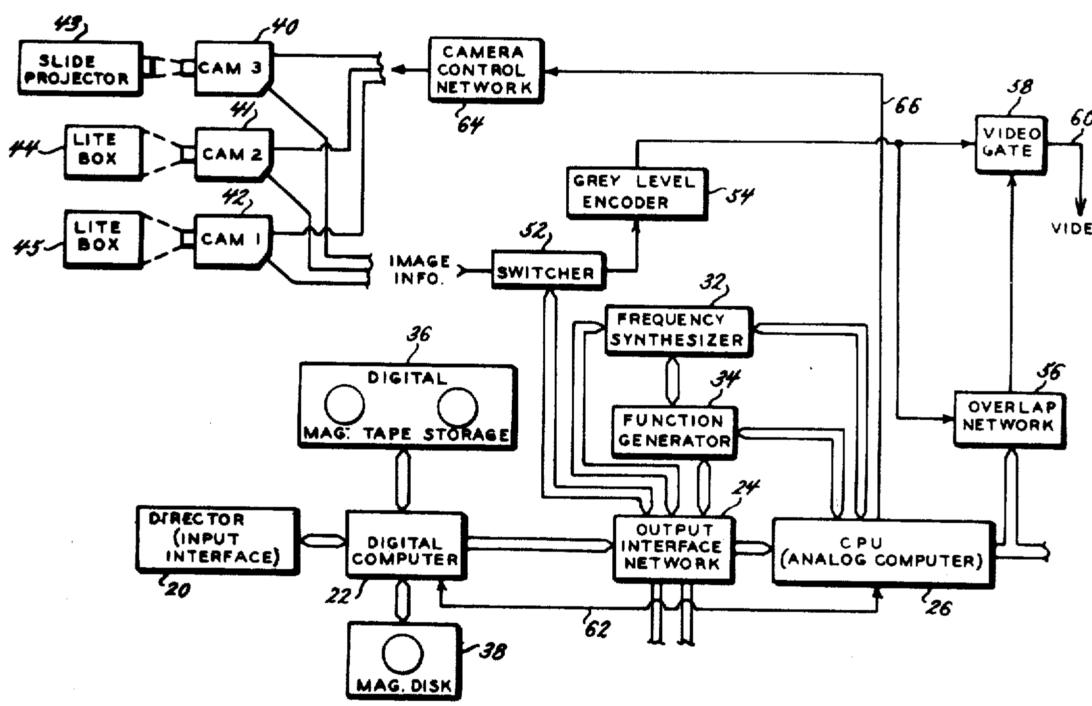
[57] **ABSTRACT**

This invention relates to a system for automatically producing an animation sequence and includes an analog portion for generating output signals representing one or more sections of a raster on which images viewed by a video camera can be produced. Analog inputs to the analog portion define the parameters of the raster sections to effectively define the shape of each part of the viewed image produced thereon. The analog inputs to the analog portion are digitally controlled by signals from a digital computer portion which establishes these digital control signals from information fed to it from a director or a recording means.

41 Claims, 13 Drawing Figures



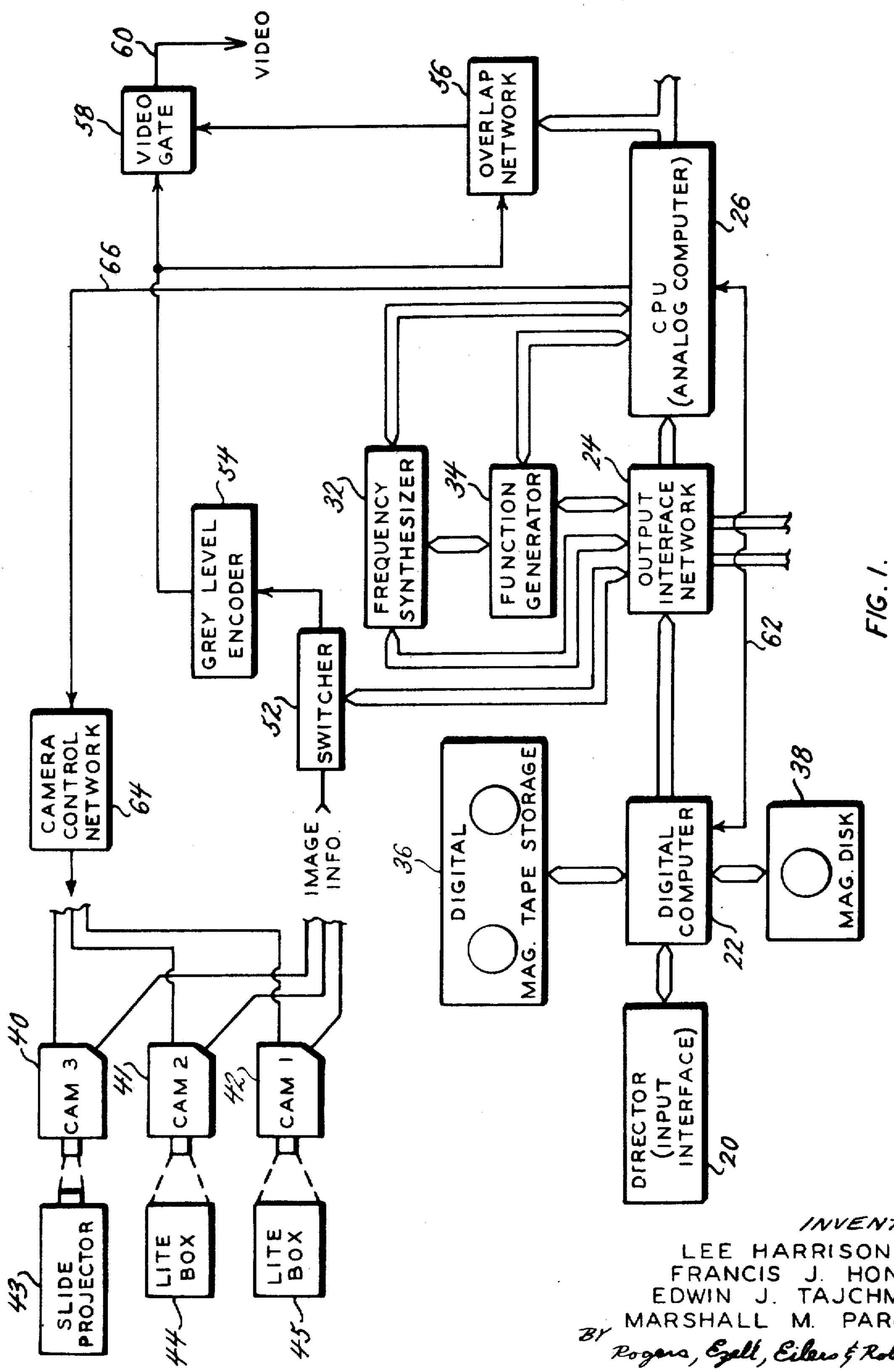


FIG. 1.

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FIG. 2.

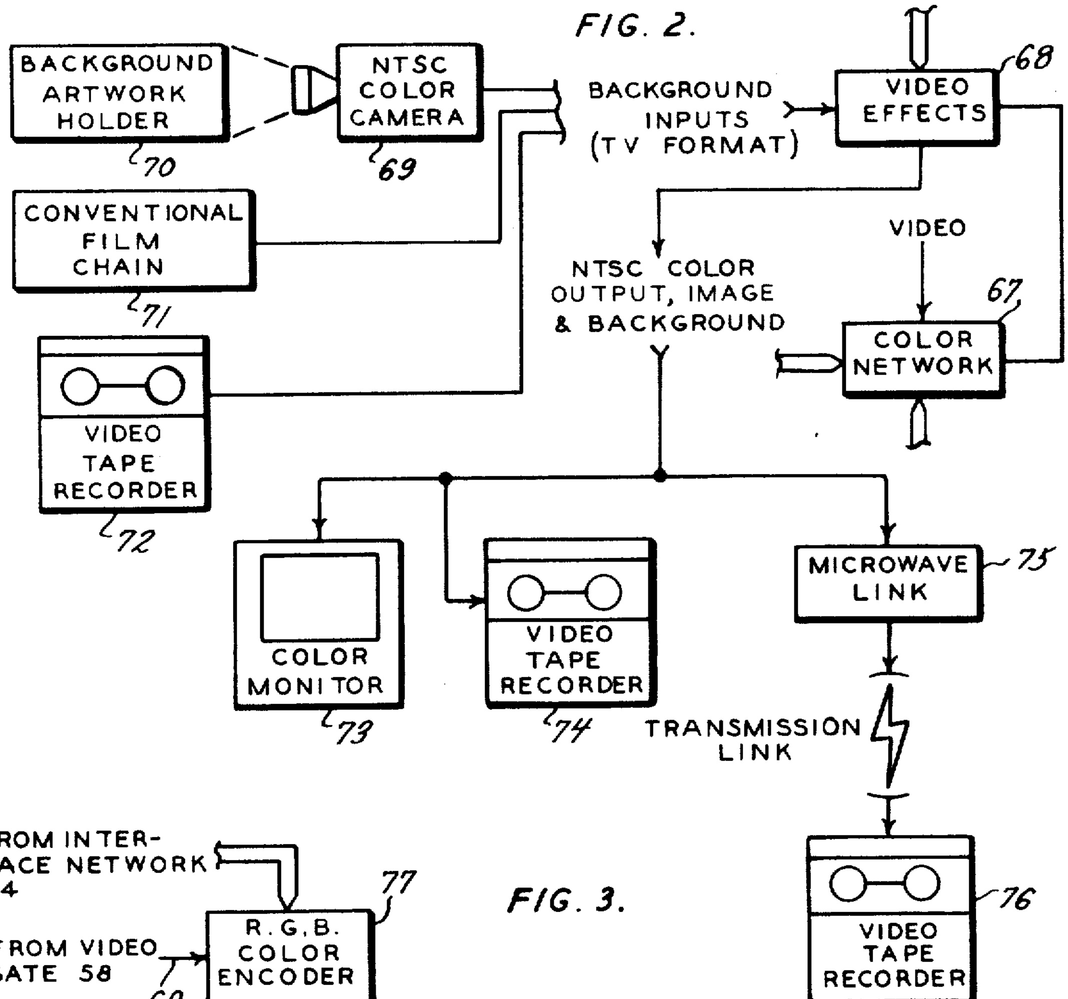
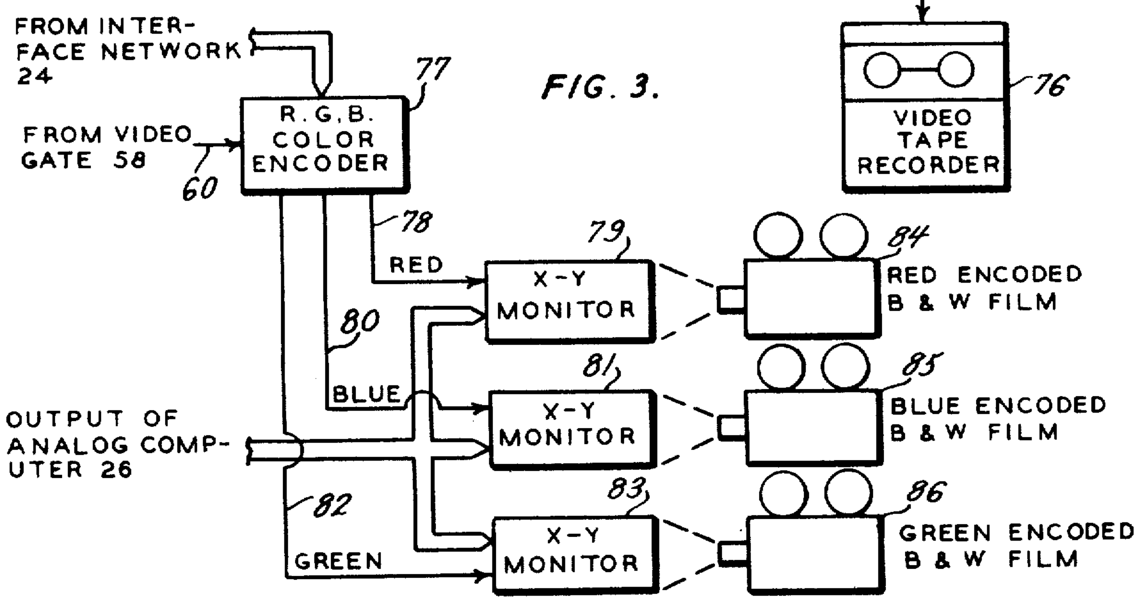


FIG. 3.



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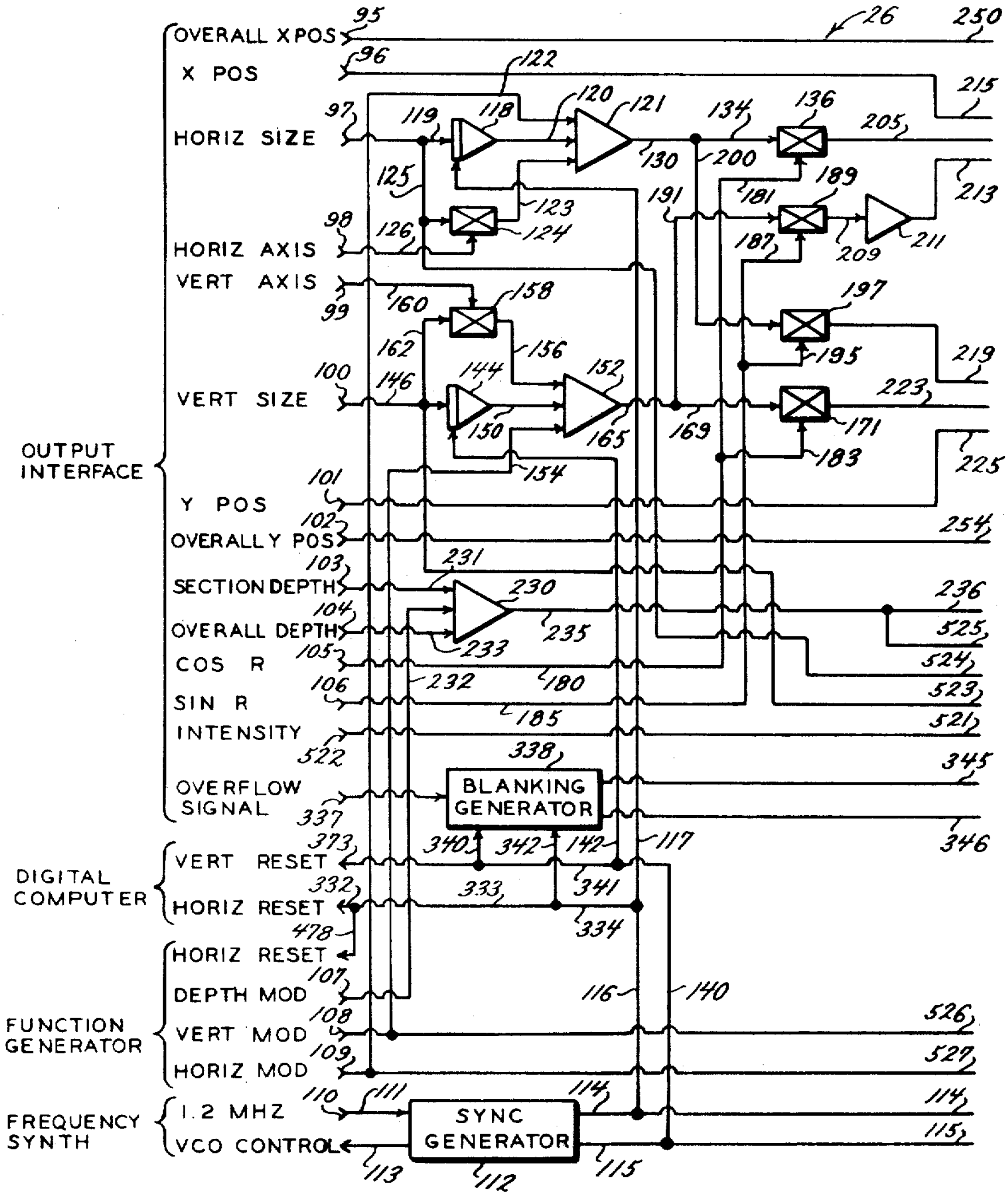

FIG. 4.

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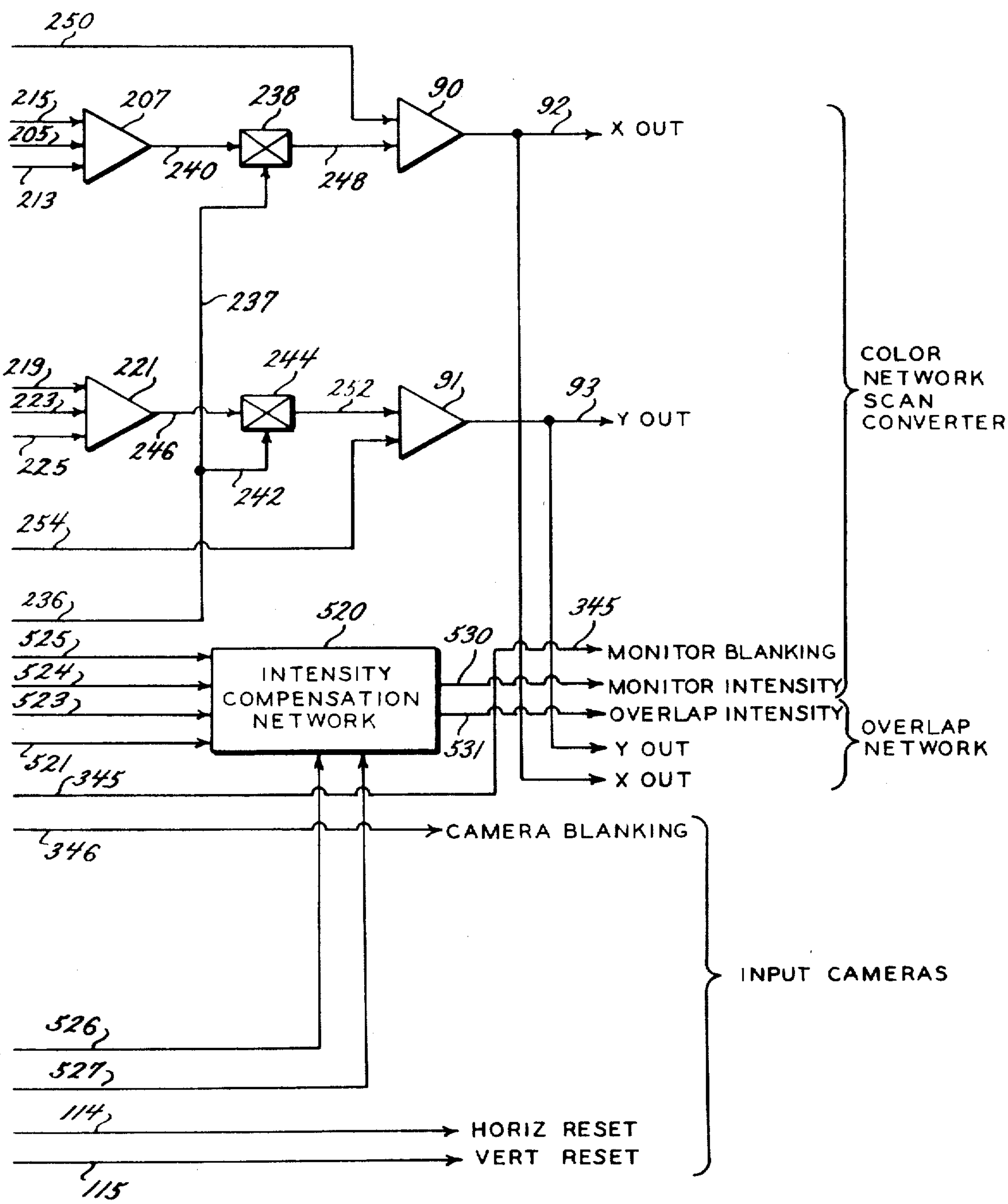

FIG. 4A.

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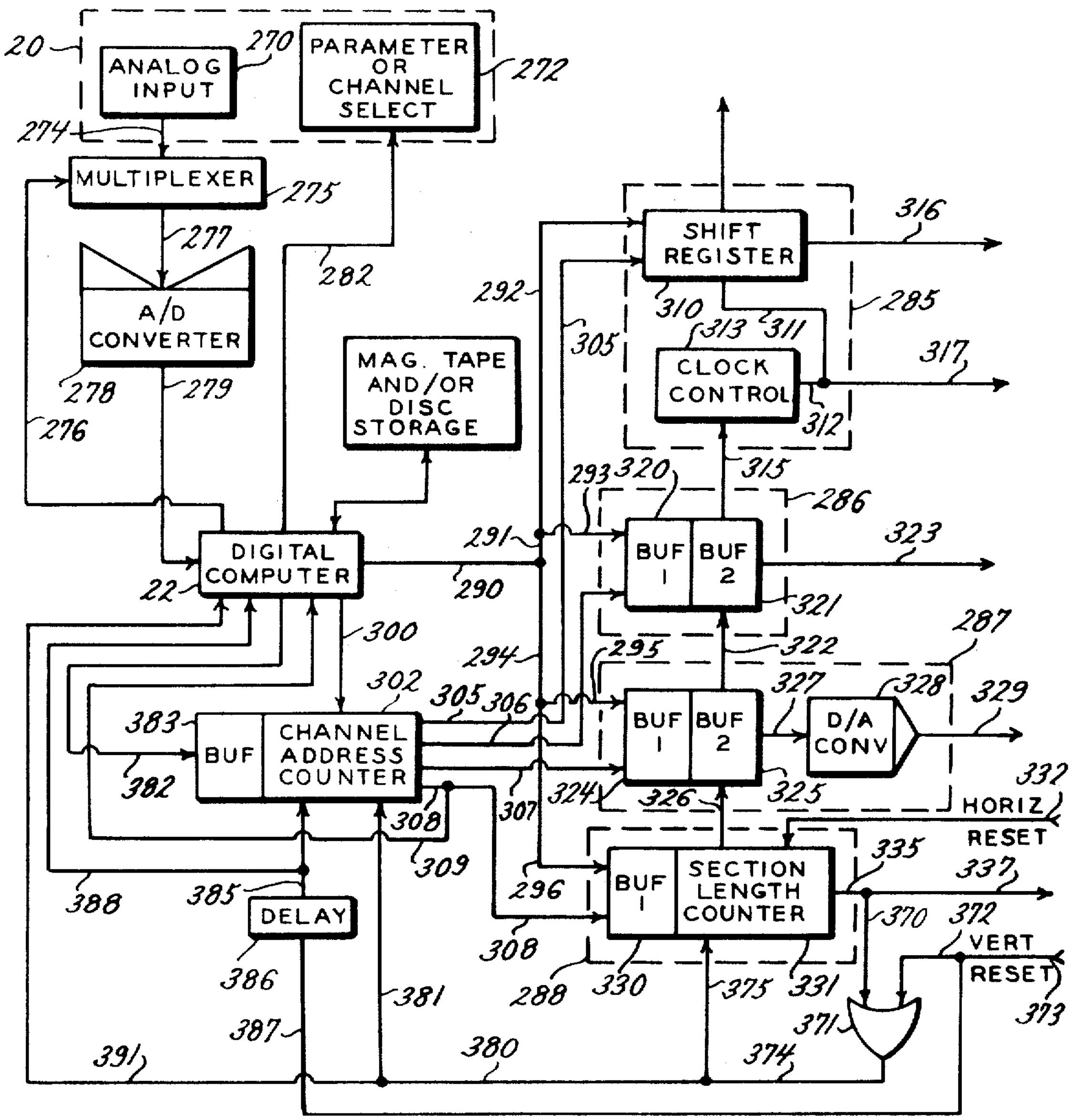

FIG. 5.

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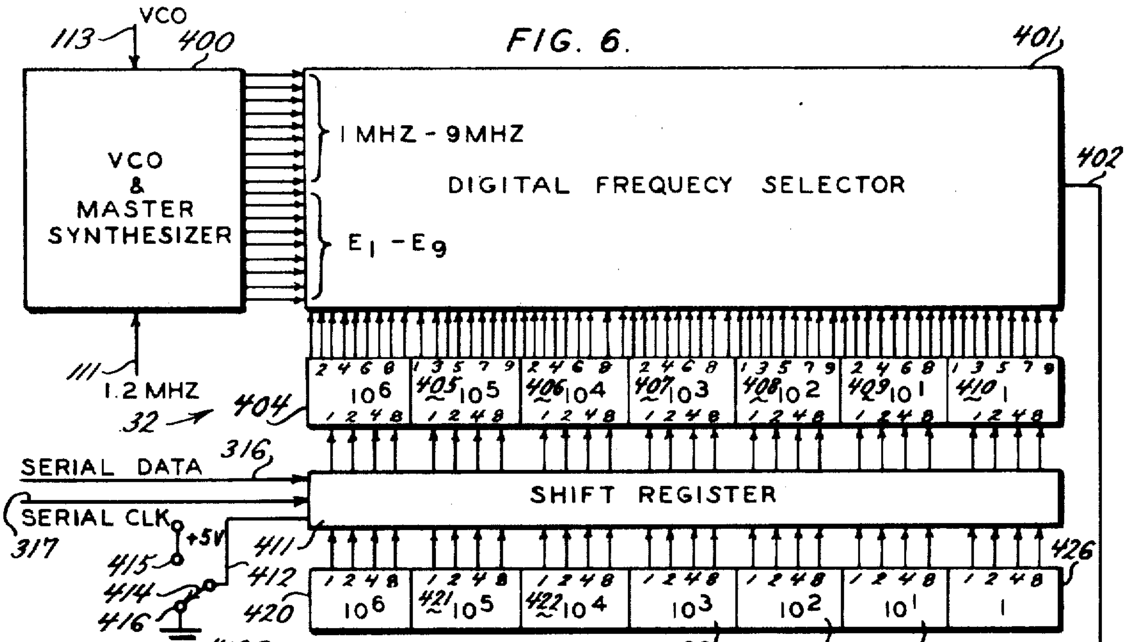
FIG. 6.



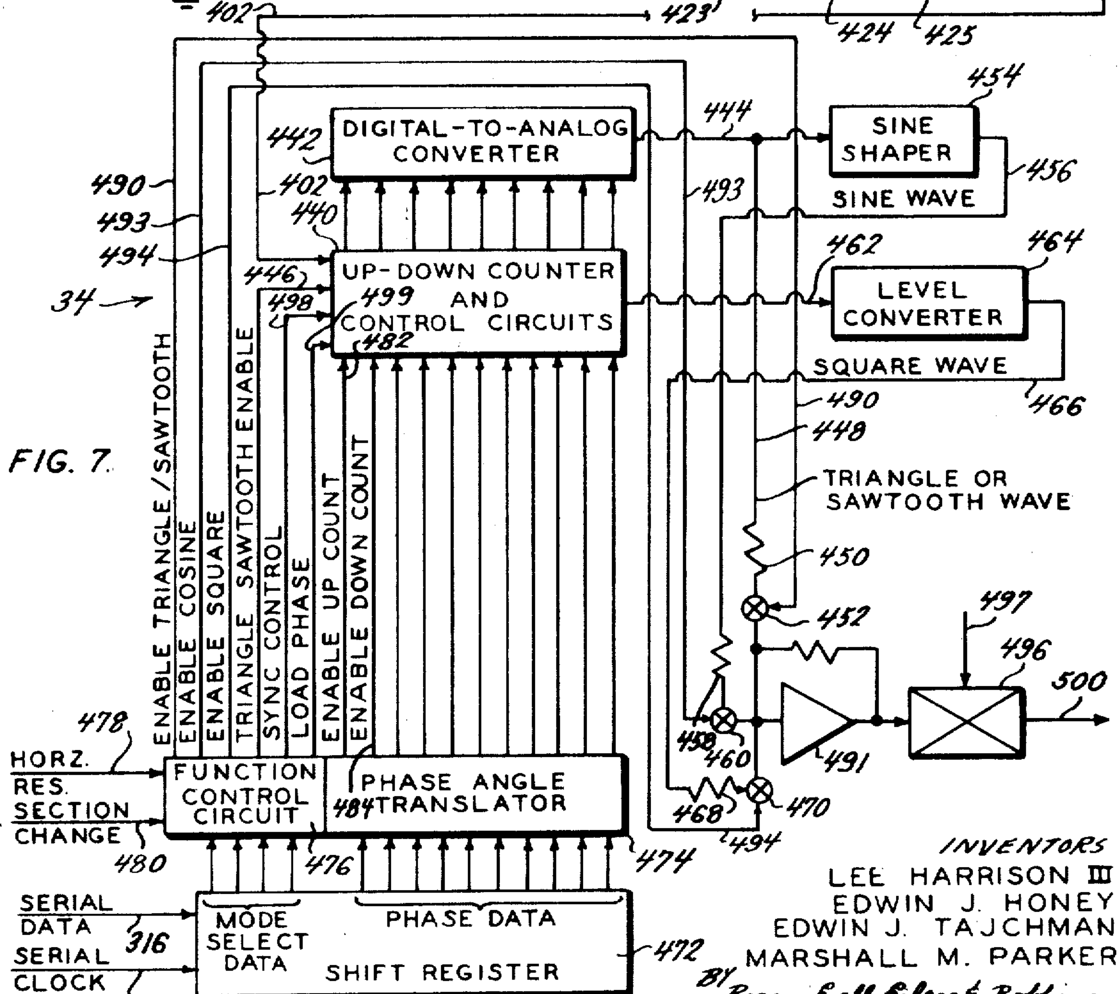


FIG. 7.

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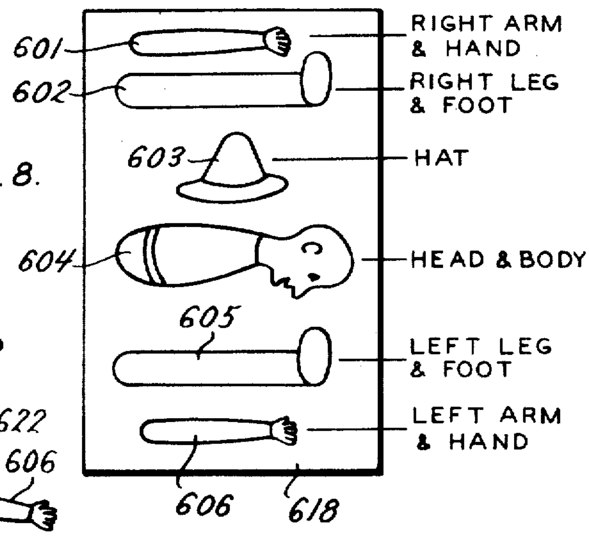
FIG. 8.



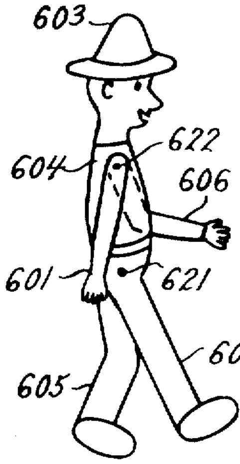


FIG. 9.

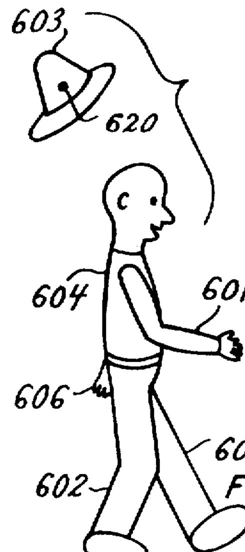


FIG. 10.

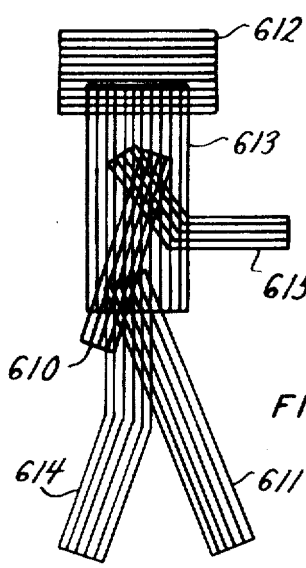


FIG. 11.

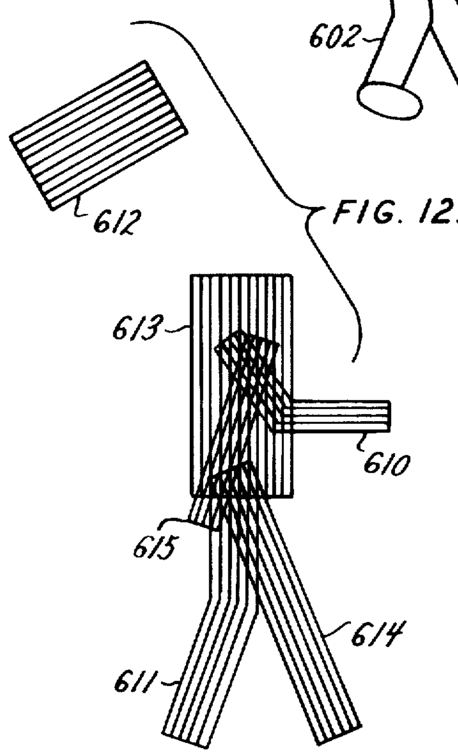


FIG. 12.

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DIGITALLY CONTROLLED COMPUTER ANIMATION GENERATING SYSTEM

CROSS REFERENCES TO COPENDING RELATED APPLICATIONS

This application relates to the disclosures of application Ser. No. 95,096 filed Dec. 4, 1970, now U.S. Pat. No. 3,710,011, and application Ser. No. 72,642, filed Sept. 16, 1970, now U.S. Pat. No. 3,689,917.

SUMMARY OF THE INVENTION

The invention of this application produces animation sequences of scenes in a way different from any other system, to create a new and novel computer animation system that provides greatly increased figure animation capability.

The system basically includes an analog portion for generating output signals representing one or more sections of a raster on which images viewed by a video camera can be produced. Analog inputs to the analog portion define the structure, size, shape, location, orientation and other parameters of the raster section to effectively define the shape of each part of the viewed image produced thereon. By varying the analog inputs, the raster section parameters can be made to vary, thus imparting motion to the image. In this system the values and variations in values of the analog inputs are controlled by digital signals from a digital computer which establishes these digital control signals from information fed to it from a director.

More specifically, the analog computer portion generates X and Y coordinate signals representing each section of an animated image for each frame of an animated sequence, each section of the image comprising a raster section. Sweep generators within the analog portion generate the basic horizontal and vertical sweep signals which are combined with, or modulated by, other input signals to define the structure, shape, size, position and other parameters of each raster section for each sequence frame. The X and Y coordinate signals at the output of the analog portion can be applied to a cathode ray tube to produce a display of the animated sequence or can be used to record the sequence on video tape or film.

The input signals to the analog portion define, for each raster section, parameters such as X and Y position, X and Y size, horizontal and vertical axes of rotation which determine the radius of rotation of each raster section, section depth, cosine and sine of the angle of rotation, intensity, and horizontal, vertical and depth modulation. Other parameter inputs define overall X and Y position and depth for the entire image. All of these parameter input signals act in conjunction with the sweep generators to ultimately produce the X and Y coordinate output signals from the analog portion for use in producing an animation sequence. By varying these input signals, each raster section can be made to vary in height or width, move anywhere in relationship to any other raster sections, rotate about any point located inside or outside the raster section, and can be modulated with the variety of modulation signals to produce bending or distortion of the raster section, which bending or distortion can be made to vary by varying modulation signal parameters such as frequency, phase and amplitude.

The parameter signals of the analog portion and the modulation signal parameters are established for each

section of the image and for each frame of the sequence by a digital computer portion which automatically calculates these parameters from information it receives at its input from a director. Parameter data for each raster section for initial and final frames of a sequence of a selected number of frames are selected on the director, which information is fed to the digital computer. The digital computer is programmed to automatically calculate, upon command, the parameter data for each section and for each frame between initial and final frames in accordance with a selected fairing function and to store this information in a digital memory such as magnetic tape or disc. Depending on the fairing function selected, these digital computations may be linear or based on some other mathematical function to define the patterns of parameter change throughout the sequence. For example, in this way an arm of a figure can be made to move at a constant rate from a first to a second position, or at a varying rate depending on the fairing function selected. The digital information recorded on the magnetic tape or disc can then be played back through the digital computer to the analog portion to produce the animated sequence.

Where a figure is displayed on the animated raster sections a video camera is trained to scan the individual parts of the figure to be animated. Timing pulses are generated to time the scan of the video camera in synchronization with the production of the X and Y coordinate output signals from the analog portion to reproduce each part of the scanned figure on a raster section as defined by the X and Y coordinate output signals. The result is that the video signals from the video camera determine the detail surface characteristics and shape of each part of the image as displayed on a raster section, while the analog portion of the computer defines the structure, shape, size, position and other parameters of each raster section as determined by the values of its parameter inputs. Digital signals from the digital computer vary the parameter inputs in a controlled manner between initial and final frames to animate the raster sections and hence the parts of the figure produced thereon to create the animation sequence.

With this system the editing is actually done by the digital computer and not after the scenes are recorded on video tape or film. By dividing a sequence to be filmed into segments or scenes having initial and final frames, the information for creating each frame of the entire sequence can be recorded on digital magnetic tape as the scenes are produced, which information can then be played back through the system for ultimate display or recording of the animation sequence on film or video tape. In this way, a sequence of any length can be produced without the need to edit the film or video tape.

Means are also provided for adding background information to the sequence and for varying the background and image foreground information by switching artwork video inputs during the sequence. The system further includes means for producing the entire sequence in colors that can be selectively varied.

From the foregoing, it is apparent that this system allows an artist to produce animated sequences in far less time than would be possible using conventional techniques (requiring 24 separate drawings for each second of animation) and yet provides him with wide control for producing many different types of animation. The

result is that the artist animates with the computer by operating the director controls, giving his full attention to creativity and results rather than the tedium of repetition.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a general block diagram of the system of this invention for generating an animation sequence;

FIG. 2 is a block diagram of a network for producing a color display or video tape of an animation sequence generated by the network of FIG. 1;

FIG. 3 is a block diagram of a network for producing a color recording on film of an animation sequence generated by the network of FIG. 1;

FIG. 4 and 4A combined are a schematic drawing of the analog computer portion of the system;

FIG. 5 is a block diagram of the control network of the system;

FIG. 6 is a block diagram of the frequency synthesizer of the system;

FIG. 7 is a block diagram of the function generator of the system; and

FIGS. 8, 9, 10, 11 and 12 are illustrations used in explaining the operation of the system.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Before describing the system components in detail, the system will be generally described by referring to the block diagrams of FIGS. 1, 2 and 3. An input interface unit 20, also called a director, generates analog and digital signals defining each parameter of each raster section for a given frame of the sequence to be generated. The values of these signals are set with analog controls, such as for example, potentiometers, and digital parameter or channel select controls, such as for example, multiposition switches, which determine the parameter or parameters being defined at a given instance by the analog control signals. The analog signals from the director 20 are converted to digital signals and fed to a digital computer 22, such as a Honeywell 316 or equivalent, which is programmed to store on appropriate command the digital information relating to each parameter of the given frame and to feed this information in a prescribed manner to an interface network 24 containing a plurality of interface units. Some of these units convert the digital parameter data from the digital computer 22 to analog parameter signals and transfer these signals to parameter inputs of an analog computer portion 26. Digital data from other interface units of the interface network 24 is fed to a frequency synthesizer 32 to define the frequencies of modulation signals used for producing certain animation effects. Digital data from still other interface units of the interface network 24 is fed to a function generator 34 for defining the phase, wave form, amplitude, and synchronization mode of the modulation signals, which signals are fed from the output of the function generator 34 to modulation parameter inputs of the analog computer portion 26. From these inputs and those from the interface units of the interface network 24, the analog computer portion 26 generates signals at its output defining raster sections. In this way such parameters as the structure, shape, size and position of each raster section generated at the output of the analog portion 26 are defined by the control settings of the director 20.

The digital computer 22 is also programmed upon receipt of parameter information from the director 20 defining initial and final frames of an animation sequence of a given number of frames to automatically calculate the parameter information defining each frame therebetween in accordance with an appropriate fairing function selector on the director, which function defines the pattern of variation for each parameter throughout the sequence, and to record the digital parameter information defining the entire sequence on a digital recording device such as a magnetic tape unit 36 or magnetic disc unit 38. Upon appropriate command from the director 20, the digital information stored on the digital tape 36 or disc 38 is played back through the digital computer 22, interface network 24, and analog computer portion 26, to produce signals at the output of the analog portion 26 representing the entire animation sequence.

The system also includes a plurality of video cameras such as 40, 41 and 42, each of which can be made to scan an art-work subject for display on the raster sections generated by the analog portion 26. The artwork subjects could be from most any source such as a slide projector 43, or light boxes 44 and 45, on which the artwork is mounted. The video information from each of the cameras 40 through 42 is sent to a switcher unit 52 which is controlled by signals from the outputs of still other interface units of the interface network 24 to switch the video of a selected one of the cameras 40 through 42 to the input of a gray level encoder 54. The encoder 54 is fully described in copending U.S. patent application Ser. No. 95,096, filed Dec. 4, 1970 now Pat. No. 3,710,011, entitled A System For Automatically Producing A Color Display of A Scene From A Black And White Representation Of The Scene. For the purposes here, it is sufficient to know that the encoder 54 produces video signals at its output representing the artwork in discrete shades of gray, which signals are fed to an overlap network 56 together with the output signals from the analog portion 26. The overlap network 56 may be of the type disclosed in FIG. 8 of U.S. Pat. No. 3,364,382 for blanking portions of the generated image appearing behind other portions of the image. To accomplish this, an output signal from the overlap network 56 is fed to a video gate 58 to gate the video signal from the output of the gray level encoder 54, through the gate 58, to an output conductor 60 only when image information is generated over an area not previously covered with other image information. Hence, the output conductor 60 carries a video signal representing the artwork in discrete shades of gray and which has been compensated for overlap prevention. This video signal can be used to reproduce the various parts of the artwork on the raster sections generated by the analog computer portion 26.

The analog computer portion 26 generates horizontal and vertical reset pulses from signals received by it from the frequency synthesizer 32. These horizontal and vertical reset pulses are fed from the analog computer portion 26 to the digital computer portion 22, as shown by conductors 62, and to a camera control network 64, as shown by conductors 66, to synchronize the generation of the coordinate output signals from the analog portion 26 defining the raster sections with the generation of the video signals on the conductor 60 representing the artwork.

The coordinate output signals from the analog portion **26** and video signals on the conductor **60** may be typically used to produce either a black and white or color display, video tape, or film of the animation sequence with the networks of FIGS. **2** and **3**. Referring to FIG. **2**, the output signals from the analog portion **26** and video signals on the conductor **60** are fed into a color network **67**, together with signals from still other interface units of the interface network **24** defining the red, blue and green color components for each discrete gray shade. The color network **67** may be of any one of the embodiments fully disclosed in the above-reference application Ser. No. 95,096 for assigning colors to each gray shade. The output from the network **67** may be used directly to produce a color display or video tape of the animation sequence, or fed to a video effects unit **68** and combined with signals representing background information in TV format, such as from a color video camera **69** photographing background artwork **70**, a conventional film chain **71**, or a video tape recorder **72**, any one of which may be used to supply background information for the sequence.

The output from the video effects network **68** is fed to a color monitor **73** for producing a color display of the animation sequence, directly to a video tape recorder **74** to produce a video tape of the sequence, or to a microwave link **75** for transmission to a video tape recorder **76**.

In FIG. **3**, there is shown a network for producing a color film of the animation sequence. The video signal on the conductor **60** and the output signals from the interface units of the interface network **24** defining the red, blue and green color components of the color to be assigned to each gray shade, are fed to an RGB color color encoder **77**, such as the type shown in FIG. **6** of the above-referenced application Ser. No. 95,096. The encoder **77** generates a video signal at an output **78** representing the red color component of each assigned color which is fed to an X-Y monitor **79**, a video signal at an output **80** representing the blue color component of each assigned color which is fed to an X-Y monitor **81**, and a video signal at an output **82** representing the green color component of each assigned color which is fed to an X-Y monitor **83**. The coordinate output signals from the analog portion **26** are also fed to each of the X-Y monitors **79, 81** and **83**, the X-Y monitor **79** producing a black and white display defining the red color components of the sequence filmed by a camera **84** on red encoded black and white film, X-Y monitor **81** producing a black and white display defining the blue color components of the sequence filmed by a camera **85** on blue encoded black and white film, and the X-Y monitor **83** producing a black and white display defining the green color components of the sequence filmed by a camera **86** on green encoded black and white film. The red, blue and green encoded films are then processed in the laboratory by known techniques to produce a composite color film of the animation sequence.

As a variation of this technique, the monitors **79, 81** and **83** could be equipped with high intensity tubes with red, blue and green phosphors, respectively, and the images produced thereon optically combined and photographed on color film.

ANALOG COMPUTER PORTION

The analog computer portion **26** will be described in more detail by referring to the network of FIGS. **4** and **4A**. The analog portion **26** includes summation amplifiers **90** and **91**. Output conductors **92** and **93**, respectively, from the summation amplifiers **90** and **91** carry X and Y coordinate signals for generating a raster section the parameters of which are defined by input signals to the analog portion **26**. By changing the values of these input signals, the values of the X and Y coordinate signals at the outputs **92** and **93** are changed, thereby changing the parameters of the raster section generated thereby.

Remembering that the coordinate output signals **92** and **93** produce a raster section the parameters of which are defined by the values of the input signals to the analog portion **26**, it can best be understood how these coordinate signals are generated and what these raster parameters are by beginning at the inputs of the analog portion **26**.

The analog portion **26** has a plurality of inputs each of which has an analog parameter signal thereon for defining the shape, size, position and structure for a given raster section represented by the X and Y coordinate outputs **92** and **93**. The signal at an input **95** defines the overall X position of the entire image comprised of a selected number of raster sections; the signal at an input **96** defines the X position of a given section of the image relative to the other sections of the image; the signal at an input **97** defines the horizontal size or length of raster lines of the given raster section; the signal at an input **98** defines the horizontal axis of rotation of the given raster section; the signal at an input **99** defines the vertical axis of rotation of the given raster section; the signal at an input **100** defines the vertical size or the spacing between raster lines of the given raster section; the signal at an input **101** defines the Y position of the given raster section relative to the other sections of an image; the signal at an input **102** defines the overall Y position of the entire image; the signal at an input **103** defines the depth or overall size of the given raster section; the signal at an input **104** defines the overall depth or overall size of the entire image; signals at inputs **105** and **106** define the cosine and sine, respectively, of an angle R, where R is the angle of rotation of the given raster section with respect to a reference axis; and inputs **107, 108** and **109** carry modulation signals from the function generator **34** to be described, for producing depth, vertical and horizontal modulations of the given raster section. The inputs **95** through **106** are from interface units of the interface network **24**, and the inputs **107** through **109** from the function generator **34**.

A 1.2 megahertz signal generated by the frequency synthesizer **32**, to be described, is fed to an input **110** and through a conductor **111** to a sync generator **112**. From the 1.2 megahertz signal, the sync generator **112** produces a 60 hertz signal for comparison with the 60 hertz line frequency and creates therefrom a voltage control oscillator (VCO) control signal at an output **113** which is fed back to the frequency synthesizer **32**. The VCO signal adjusts the frequency of the 1.2 megahertz signal to insure that the 60 hertz signal generated by the sync generator **112** is locked to the line frequency. The generator **112** generates at one of its outputs **114** a horizontal reset signal of a frequency of 28.35 kilohertz, and at another output **115** a vertical reset signal of a frequency of 60 hertz. As will be seen, these horizontal and vertical reset signals are used

throughout the system to synchronize various timing operations.

The horizontal reset signal on the conductor **114** is fed through a conductor **116** and a conductor **117** to the reset input of an integrator **118**. Another input conductor **119** to the integrator **118** is connected from the input **97** defining the horizontal size of a particular raster section. Therefore, after each horizontal reset pulse the integrator **118** operates as a horizontal ramp generator to draw a line of the raster section of a length determined by the magnitude of the signal at the input **97**. The output of the integrator **118** is fed through a conductor **120** to one input of a summation amplifier **121**. The summation amplifier **121** has another input conductor **122** connected to the input **109** carrying the horizontal modulation signal from the function generator **34**. Another input conductor **123** to the summation amplifier **121** is connected from the output of a multiplier **124** having one input connected by a conductor **125** to the horizontal size input **97**, and having another input conductor **126** connected to the input **98** defining the horizontal axis of rotation of the section. Therefore, the purpose of the multiplier **124** is to insure that where there is an increase in the horizontal size of the raster section, there is automatically a corresponding change in the horizontal axis of rotation of that section to insure that the section rotates about the same relative point. The output of the summation amplifier **121**, representing the sum of the horizontal ramp function, the horizontal modulation signal, and the product of the signals representing the horizontal axis of rotation and the horizontal size of the raster section is fed through a conductor **130** and a conductor **134** to one input of a multiplier **136**.

The vertical reset signal at the output **115** from the sync generator **112** is fed through a conductor **140** and a conductor **142** to the reset input of an integrator **144**. The integrator **144** has an input conductor **146** connected from the analog computer input **100** defining the vertical size of each raster section so that each time after the integrator **144** receives a vertical reset pulse, it generates a vertical ramp function defining the height of the raster section (the distance between the raster lines) in accordance with the magnitude of the signal at the input **100**. The output of the integrator **144** is fed through a conductor **150** to one input of a summation amplifier **152**. Another input conductor **154** to the summation amplifier **152** is connected from the input **108** to the analog portion carrying the vertical modulation signal from the function generator **34**. Another input conductor **156** to the summation amplifier **152** is connected from the output of a multiplier **158** having one input connected by a conductor **160** to the input **99** of the analog portion carrying the signal defining the vertical axis of rotation of the raster section, and another input conductor **162** connected from the vertical size input **100**. The multiplier **158** performs the same function with respect to compensating for changes in vertical size as the multiplier **124** does for compensating for changes in horizontal size. That is, where there is a change in the vertical size of the raster section, the multiplier **158** insures that there is automatically a corresponding change in the vertical axis of rotation so that the point of rotation remains in the same relative position. The output from the summation amplifier **152** representing the sum of the vertical ramp signal, the vertical modulation signal, and the product of the signals defining the vertical axis of rotation and vertical size of the raster section is fed through a conductor **165** and a conductor **169** to one input of a multiplier **171**.

To provide a wide variety of animation capability, this system includes means for rotating each raster section about a point defined by the horizontal and vertical axes inputs **98** and **99** and through an angle, which will be called R, the cosine and sine of which are defined by voltages at the inputs **105** and **106**, respectively, to the analog portion **26**. The system further includes means for rotating any raster distortion with the raster. To illustrate the importance of these rotation capabilities, consider the problem of producing an animation sequence of a walking figure. As the figure moves, the legs must bend at the knees and rotate at the hips, and the arms must bend at the elbows and rotate at the shoulders. Taking one of the arms as an example, as the raster section on which the arm is produced rotates causing rotation of the arm about the shoulder, the raster distortion pattern creating the bend at the elbow, which bend is produced by a selected vertical modulation signal from the function generator **34**, must also rotate or else an unnatural or undesirable distortion of the arm will result. For this reason, rotation is imparted to the raster section after the modulation signals are summed with the horizontal and vertical ramp signals. Hence, the signal at the input **105** representing the cosine of R is fed through a conductor **180** and a conductor **181** to a second input of the multiplier **136**, and through a conductor **183** to a second input of the multiplier **171**. The signal at the input **106** representing the sine of R is fed through a conductor **185** and a conductor **187** to one input of a multiplier **189**, the other input of which is connected by conductor **191** to the output of the summation amplifier **152**. The signal on the conductor **185** representing the sine of R is also fed through a conductor **195** to one input of a multiplier **197** having another input connected by a conductor **200** to the output of the summation amplifier **121**. The output from the multiplier **136** representing the product of the output from the summation amplifier **121** and the cosine of R is fed through a conductor **205** to one input of a summation amplifier **207**. The output from the multiplier **189** representing the product of the output from the summation amplifier **152** and the sine of R is fed through a conductor **209**, an inverter **211** and a conductor **213** to a second input of the summation amplifier **207**. The summation amplifier **207** has a third input conductor **215** connected from the input **96** of the analog portion **26** carrying the signal defining the X position of the section. The output from the multiplier **197** representing the product of the output from the summation amplifier **121** and the sine of R is fed through a conductor **219** to one input of a summation amplifier **221**. The output from the multiplier **171** representing the product of the output from the summation amplifier **152** and the cosine of R is fed through a conductor **223** to a second input of the summation amplifier **221**. The summation amplifier **221** has a third input conductor **225** connected from the input **101** of the analog portion **26** carrying a signal defining the Y position of the raster section.

A summation amplifier **230** has one input connected by a conductor **231** to the input **103** of the analog portion carrying the signal defining the depth of the raster section, another input connected by a conductor **232** to the input **107** of the analog portion carrying the

depth modulation signal from the function generator 34, and another input connected by a conductor 233 to the input 104 of the analog portion carrying the signal defining the overall depth of the entire image. The output from the summation amplifier 230 representing the sum of these depth signals is fed through a conductor 235, a conductor 236, and a conductor 237 to one input of a multiplier 238. The output from the summation amplifier 207 is fed through a conductor 240 to a second input of the multiplier 238. The output from the summation amplifier 230 is also fed through the conductors 235 and 236 and through a conductor 242 to one input of a multiplier 244, the other input of which is connected by a conductor 246 to the output of the summation amplifier 221. The output from the multiplier 238 representing the product of the signals from the summation amplifiers 207 and 230 is fed through a conductor 248 to one input of the summation amplifier 90. Another input of the summation amplifier 90 is connected by a conductor 250 to the input 95 of the analog portion 26 carrying the signal defining the overall X position of the image. The output from the multiplier 244 representing the product of the signals from the summation amplifiers 221 and 230 is fed through a conductor 252 to one input of the summation amplifier 91. Another input of the summation amplifier 91 is connected by a conductor 254 to the input 102 of the analog portion 26 carrying the signal representing the overall Y position of the image. Hence, the output from the summation amplifier 90 represents the X coordinate signal for the raster section, and the output of the summation amplifier 91 represents the Y coordinate signal for the raster section.

From the above description, it is apparent that the analog portion 26, given a set of fixed input parameter signals, generates a raster section of a particular size, shape, structure, and position as defined by these input signals. If the input parameter signals remain constant over time, identical raster sections will be generated repeatedly. If, on the other hand, the input parameter signals are changed in a prescribed manner over a prescribed time interval, a plurality of raster sections, each shaped, sized, structured and positioned differently from the others, are generated. Furthermore, by changing the input parameter signals defining each raster section at prescribed increments and at a prescribed frequency, motion can be imparted to the rasters and hence the image, to produce an animation sequence. The control of the input parameter signals to the analog portion 26 to produce and animate the different raster sections is accomplished with the control network of FIG. 5.

CONTROL NETWORK.

In generating an animation sequence, the control network operates in basically three modes: a frame reference mode, a record mode, and a playback mode.

In the frame reference mode the digital computer 22 receives digital parameter information from the director 20 for establishing initial and final frames for the sequence. The director 20 has an analog input portion 270 (which might include, for example, a plurality of potentiometers or the like) for generating analog signals which might be used to define any raster parameter, and a parameter select input 272 (which might include multiposition switches) for selecting the parameter to be defined by the analog signal from the analog input 270. The analog input signals from the analog input 270 selected for particular ones of these parameters are fed through suitable conductors 274 to one input of a multiplexer 275 having another input connected by conductor 276 to an output from the digital computer 22 which carries signals in accordance with its program to gate the analog information from the analog input 270 in a prescribed sequence through conductors 277 to the input of an analog to digital converter 278. The digital output signals from the converter 278 are fed through conductors 279 to an input of the digital computer 22.

The computer 22 is programmed to store the information received from the analog input 270 and to interrogate through appropriate conductors 282 the parameter select unit 272 to determine the parameter to which each piece of stored information pertains. Having made this determination, the parameter information is transferred to an appropriate storage location within the computer 22. By manipulating the analog input 270 and parameter select 272 controls, digital signals are eventually stored in the appropriate memory locations of the digital computer 22 representing each parameter of each raster section of the image for the initial frame of the sequence. Having stored the initial frame information, the same procedure is followed for establishing the digital parameter information for the last frame of the sequence.

Having established the initial and final frame parameters for the sequence the digital computer 22 can now be placed in the record mode. In this mode the digital computer 22 is programmed to calculate, upon command from the director 20, the digital parameter information defining each raster section of each frame between initial and final frames, and to record this information on the digital recording device such as magnetic tape 36 of disc 38. These calculations are made in accordance with a selected one of several mathematical functions called fairing functions which define the rate of change of each parameter from frame to frame throughout the sequence. For example, if a linear fairing function is selected, the rate of parameter change from frame to frame is constant, while other fairing functions produce varying change rates. The computer 22 is programmed to make its calculations in accordance with any one of the several fairing functions, a particular function selected by command signal from the director 20.

With the digital parameter information defining each raster section of each frame of the sequence recorded on the digital recording device, the control network can be placed in its playback mode to play the recorded digital parameter information back to the digital computer 22 where it is stored in a prescribed sequence in various memory locations.

In this manner digital parameter information is fed to and stored in the digital computer 22 for transfer to other networks of the system such as the analog portion 26, frequency synthesizer 32, and function generator 34, to generate the sequence. The manner in which this transfer is accomplished is the time regardless of its source (whether from the director 20 or digital magnetic recording devices 36 or 38) and will not be explained.

As parameter information from one of the input sources is stored at some memory location within the computer 22, the computer 22 is programmed to trans-

mit this information sequentially at high speed, and in a specified order to interface units within the interface network **24.** In this described embodiment of the invention there are basically four types **285, 286, 287** and **288** of these interface units. There may be any number of each type depending on the number of parameters to be defined. For example, in this embodiment there are nine units of the type **285,** two units of the type **286,** 31 units of the type **287,** and one unit of the type **288** for a total of 43 interface units, each to affect a different parameter as each raster section of an image frame is drawn. There are, therefore, at least as many interface units as there are parameters to be defined for each raster section generated.

The information stored in the digital computer **22** defining each parameter is fed in an order determined by the digital computer program to each of the interface units. Hence, for example, the information defining a first parameter of a given raster section is fed through conductors **290, 291** and **292** to an interface unit of the type **285;** conductor **290, 291** and **293** to an interface unit of the type **286;** conductors **290, 294** and **295** to an interface unit of the type **287;** and conductors **290, 294** and **296** to an interface unit of the type **288;** and so on for the information defining the second and succeeding parameters until all of the parameter information defining a particular raster section of the frame is fed to the inputs of each interface unit.

As the information defining the first parameter is fed to each interface unit at high speed, a signal is sent from the digital computer **22** through a conductor **300** to a channel address counter **302** which has a separate output connected to a gate input of each interface unit. To illustrate, there is an output conductor **305** connected to a gate input of the interface unit of the type **285,** an output conductor **306** connected to a gate input of the interface unit of the type **286,** an output conductor **307** connected to a gate input of the interface unit of the type **287,** and an output conductor **308** connected to a gate input of the interface unit of the type **288.**

In this embodiment with 43 interface units, the counter **302** would have 43 such output conductors each connected to a gate input of an interface unit. Each time the digital computer **22** feeds information defining a parameter for a particular raster section to each interface unit it sends a signal through the conductor **300** to activate an appropriate one of the outputs of the counter **302** which in turn gates the information which is present at the inputs of all the interface units to the appropriate one of these units. The digital computer **22** is programmed to feed the digital parameter information in the proper sequence so it is gated to the appropriate interface unit to effect the appropriate parameter input to the system.

When the last output conductor, which for purposes of illustration might be the conductor **308,** of the counter **302** is activated to gate digital parameter information to the last interface unit, all the units are loaded and the high speed transfer of information from the digital computer **22** relating to the next raster section to be generated must be stopped. Hence, the gating signal on the last output conductor **308** of the counter **302** is also fed through a conductor **309** to an input of the digital computer **22** to stop the high speed transfer. As will be seen, the high speed transfer of information from the digital computer **22** will be started again to reload the interface units with information by the start of a vertical reset or a section change pulse defining the next raster section.

Each of the types of interface units **285** through **288** is designed differently to perform a different interface function and for interface with a different part of the system. The unit type **285** is used for interface with the frequency synthesizer **32** and function generator **34** for defining the frequency, phase, waveform, and synchronization mode parameters of the modulation oscillators for use in creating vertical, horizontal and depth modulation. In this embodiment, two such units are required to define frequency, and one for phase, waveform and synchronization mode. With vertical, horizontal, and depth modulation, nine such units are used. Each unit type **285** includes a shift register **310** having one input, connected by conductors **290, 291,** and **292** to the output of the digital computer **22** for receiving the digital parameter information, an input connected by the conductor **305** to an output of the channel address counter **302** for gating the appropriate digital parameter information into the shift register **310,** and an input connected by a conductor **311** and a conductor **312** to the output of a clock control **313.** The clock control **313** has an input **315** connected to the output of an OR gate to be described. When the clock control **313** receives a signal at its input **315,** it transmits a series of pulses through the conductors **312** and **311** to the input of the shift register **310** to feed the digital parameter information in the shift register **310** serially through an output conductor **316** to the frequency synthesizer **32** or function generator **34.** The clock pulses from the output of the clock control **313** are also fed through a conductor **317** to the frequency synthesizer **32** or function generator **34.**

Each interface unit of the type **286** includes a first buffer **320** and a second buffer **321,** the input of which is connected to the output of the buffer **320.** The buffer **320** has one input connected by the conductors **290, 291** and **293** to the output of the digital computer **22** for receiving the digital parameter information, and an input connected by the conductor **306** to an output of the channel address counter **302** for gating the appropriate digital parameter information into the first buffer **320.** The second buffer **321** has an input **322** which, like the input **315** of the clock control **313,** is connected to the output of the OR gate. On appropriate signal at the input **322,** the digital parameter information in the first buffer **320** is transferred to the second buffer **321** and through an output conductor **323** to provide digital control signals available for such operations as section blanking and video switching. In this embodiment, two such unit types **286** are used, although, of course, the number depends on the number of digital control signals required for various contolling operations.

An interface unit of the type **287** is used to interface with each of the parameter inputs **95** through **106** of the analog portion **26,** and the function generator **34** to define the amplitudes of the modulation signals. Since there are vertical, horizontal, and depth modulations, three such units are required for this purpose. Units of this type are also used to interface with the color network **67** or RGB color encoder **77** of FIGS. **2** and **3,** for defining the colors of each frame of the image. For example, where each frame has five different colors (five discrete shades of gray, a color for each shade), and

since each color has a red, blue and green color component, 15 such units are required. A unit of this type is also used to interface with an intensity compensation network, to be described.

Each interface unit of the type **287** includes a first buffer **324** and a second buffer **325**, the input of which is connected to the output of the first buffer **324**. The first buffer **324** has an input connected by the conductors **290, 294** and **295** to the output of the digital computer **22** for receiving the digital parameter information. The buffer **324** also has an input connected by the conductor **307** to an output of the channel address counter **302** to gate the appropriate digital parameter information into the buffer **324**. For example, this information might define one of the color parameters, or an amplitude parameter for a modulation oscillator, or one of the input parameters **95** through **106** to the analog portion **26**. The buffer **325** has an input **326** which, like the inputs **315** and **322** to the units **285** and **286**, is connected to the output of the OR gate. Upon receiving an appropriate signal at the input **326**, the digital information in the buffer **324** is transferred to the buffer **325** and fed through the conductors **327** to the input of a digital to analog converter **328** which converts the digital information to an analog signal for transmission through its output conductor **329** to the appropriate parameter input of the system.

The interface unit type **288** has the dual function of defining the number of raster lines in each raster section and timing the transfer of parameter information from the digital computer **22** to the parameter inputs of the analog portion **26** and other parameter inputs of the system. In this described embodiment, there is only one interface unit of the type **288** required in the system. It includes a buffer **330** and a section length counter **331**, an input of which is connected to the output of the buffer **330**. The buffer **330** has one input connected by conductors **290, 294** and **296** to the output of the digital computer for receiving the digital parameter information, and an input connected by the conductor **308** to the appropriate output of the channel address counter **302** for gating into the buffer **330** the digital parameter information from the digital computer **22** which defines the number of lines in the section being generated. The section length counter **331** has an input conductor **332** which is connected by conductors **333, 334, 116** and **114** to the horizontal reset output of the sync generator **112** (FIG. 4). The section length counter **331** continuously counts the horizontal reset pulses on its input conductor **332** and upon reaching a prescribed count, generates an overflow or section change signal at an output conductor **335**. How long the counter **331** must count to generate the overflow signal depends on the digital information fed to it from its input buffer **330**. The length of the count by the counter **331** defines the number of lines in the section being generated.

When the counter **331** stops counting and generates the section change signal at its output, this signal is fed through the conductor **335** and a conductor **337** to an input of a blanking generator **338** (FIG. 4). The blanking generator **338** has another input connected by a conductor **340**, a conductor **341** and the conductors **140** and **115** to the vertical reset output of the sync generator **112**, and another input connected by a conductor **342** and in the conductors **334, 116** and **114** to the horizontal reset output of the sync generator **112**. Upon receiving a section change signal from the counter **331**, the blanking generator **338** generates a signal at its output which is fed through a conductor **345** for use in blanking the beam of a monitor used for displaying the image or a scan converter used in producing the image in TV format. The blanking generator **338** is set to generate the blanking signal for a period of time equivalent to approximately two horizontal raster lines, although this period is adjustable. The blanking generator **338** generates another signal at an output which is fed through a conductor **346** for use in blanking the beam of the artwork scanning camera, such as the camera **40, 41** or **42**, a monitor used for displaying the image, or a scan converter used in producing the image in TV format, between each scan cycle and raster line. For example, where as is customary there are two interlacing scan cycles or fields per frame, the blanking signal on the conductor **346** blanks the beam between each field and raster line. This, of course, is to insure that the beam is turned off during flyback from the end of one scan or line to the beginning of the next.

The section change signal on the output conductor **335** of the section length counter **331** is also fed through a conductor **370** to one input of an OR gate **371** which has another input connected by a conductor **372**, a conductor **373**, and the conductors **341, 140** and **115** to the vertical reset output of the sync generator **112**, (FIG. 4). The output of the OR gate **371** representing either the vertical reset or section change signals is fed through a conductor **374** to a preset input **375** of the section length counter **331** to preset the counter at the end of each raster section and frame, or at the end of each raster section and field if there are two fields per frame, to a count defined by the digital parameter information in the buffer **330**. At the same time, the OR gate output signal is fed to the input **326** of each interface unit of the type **287** to transfer the digital parameter information in the buffer **324** through the buffer **325** and converter **328** to the appropriate inputs of the system; to the input **322** of each interface unit of the type **286** to transfer the digital parameter information in the buffer **320** through the buffer **321** and on to the appropriate parameter inputs of the system; and to the input **315** of each unit of the type **285** to transfer the digital parameter information in the shift register **310** serially to the appropriate input of the system. Hence, the section change signal from the section length counter **331** not only initiates the blanking of raster lines between the raster secitons, but acts with the vertical reset signal to determine the number of lines in each raster section, by simultaneously transferring the digital parameter information in each interface unit which defines a new raster section to the appropriate inputs of the system.

The signal at the output of the OR gate **371** is also fed through the conductor **374**, a conductor **380**, and a conductor **381** to a preset input of the channel address counter **302** to preset the counter to a number determined by information fed through a conuctor **382** to a buffer input **383**. The preset number determines the starting count from which counter **302** addresses the interface units. This count may vary from raster section to raster section. For example, there are certain parameters that remain constant from section to section in a given frame, such as overall X position, overall Y position, and overall depth as these parameters affect all the sections of the image. Color parameters might also

remain constant. To illustrate, if the informaiion for these overall parameters occupies the first 18 interface units, it is necessary to reload these units after each section. Therefore, the counter **322** should be preset to begin its address with the 19th interface unit after the parameter information for the first section of the frame is transferred. The digital computer **22** is programmed to transmit the desired preset value to the input buffer **383**.

The channel address counter **302** also has an input connected by a conductor **385** to the output of a delay network **386**, the input of which is connected by a conductor **387** and the conductors **373, 341, 140** and **115** to the vertical reset output of the sync generator **112** (FIG. **4**), to reset the counter **302** just before the end of each frame or field, if there are two fields per frame. The delay network **386** generates a signal at its output that is delayed from the vertical reset signal by approximately 90 percent of the time period between vertical reset pulses. Therefore, in effect, there is a pulse generated at the output of the delay network **386** that occurs just prior to each vertical reset pulse after the first vertical reset pulse is generated. These pulses from the output of the network **386** are also fed through a conductor **388** to an input of the digital computer **22** to enable the computer **22** for high speed transfer of parameter data.

The signal from the output of the OR gate **371** is also fed through the conductors **374** and **380,** and a conductor **391** to an input of the digital computer **22** to start the high speed transfer from the computer **22** to the interface units of the digital parameter information for the next raster section to be generated.

Reviewing the operation of the network of FIG. **6,** digital information is stored wthin the computer **22** definin the parameters of each raster section of the image to be generated for a given frame or frames. The origin of the information may be the director **20** which includes controls for setting the value of each set of parameter information to define each raster section of a particular frame, or may be some digital recording medium such as the digital magnetic tape **36** or disc **38** on which is recorded parameter informatinn defining each raster section of each frame of a sequence. As the information is being stored, an output pulse from the delay network **386** is fed through the conductor **388** to initiate the high speed transfer of the digitial parameter information defining the first raster section of the first frame which is fed in a prescribed order in accordance with the digital computer program from the output of the computer **22** to each of the interface units of which in this described embodiment there are a total of 43, including four different basic types. The signal at the output of the delay network **386** initiates the high speed transfer for the first section parameter data only, the high speed transfer of parameter data for subsequent sections being initiated by the vertical reset or section change signals. As the digital parameter information is fed to the interface units, signals are fed through the conductor **300** to the channel address counter **302** generating signals sequentially at a different one of its outputs, each one of which is connected to a different interface unit to gtte the appropriate digital parameter information from the computer **22** to the appropriate one of the interface units. Hence, the interface units are loaded sequentially with the appropriate information defining the parameters of the first raster section. When the gating signal appears at the last output of the channel address counter **302,** indicating that all the interface units are loaded, this signal is fed through the conductors **308** and **309** to an input of the computer **22** to stop the high speed tansfer of digital parameter information.

It will be remembered that the purpose of the interface unit **288** is to define the number of lines in the raster section currently being drawn. However, because the information loaded in the interface units relates to the first raster section, the interface unit **288** cannot perfomr this function as there is no raster section currently being drawn. Nevertheless, when the next vertical reset signal is generated by the sync generator **112** it is fed through the conductors **115, 140, 341, 373** and **372** the OR gate **371,** and the conductor **374** to the inputs **375, 326, 322** and **315** of the interface units to simultaneously transfer the digital parameter information loaded in these units and the others like them defining the parameters of the first raster section to the appropriate parameter inputs of the system, and to preset the section length counter **331.** This same vertical reset signal is also fed through the conductors **380** and **391** to an input of the digital computer **22** to start the high speed transfer of digital parameter information defining the second section to the interface units. The vertical reset signal is also fed through the conductor **381** to preset the channel address counter **302** to a number defined by information fed from the computer **22** through the conductor **382** into its input buffer **383.** The delayed vertical reset pulse at the input **385** to the counter **302** resets the counter **302** just prior to the start of each frame or field, if there is more than one field per frame.

Along with the other dilital parameter information from the digital computer **22** defining the first raster section is information defining the number of lines in the first raster section which is now being generated at the output of the analog portion **26.** This information is fed to the interface unit **288** together with the horizontal reset pulses from the sync generator **112.** The section length counter **331** counts the horizontal reset pulses at its input **332** for a length of time defined by the value of the information which was transferred from its input buffer **330.** When it has reached a full count, a section change signal is generated at its output which is fed through the conductors **335** and **337** to the blanking generator **338** which generates a signal that blanks the first two or three raster lines of the next raster section (which would be the second raster section). This same section change signal is fed through the conductors **335** and **370** and the OR gate **371** to perform the same functions with respect to the second section as the vertical reset signal did with respect to the first, that is, to simultaneously transfer the digital parameter information loaded in the interface units defining the parameters of the second raster section to the appropriate parameter inputs of the system and to preset the section length counter **331,** to start the high speed transfer of digital parameter information defining the third section to the interface units, and to preset the channel address counter **302** to a number defined by information fed to its buffer input **383** from the digital computer **22.**

The process then repeats itself for the next section and each succeeding section of the first frame, each time sequentially loading the interface units with pa-

rameter information and transferring this information simultaneously to the appropriate inputs of the system to generate the next raster section until the initial frame is generated. The process is then repeated for each succeeding frame of the sequence.

If the parameter information stored within the digital computer **22** remains unchanged, each frame will be identical. If however, the parameter information within the digital computer is changed, as for example by manipulatinn of the control settings of the analog input **270** and parameter select input **272** of the director **20**, or by the sequential playback of digital parameter information recorded on the digital storage medium such as magnetic tape **36** or disc **38** into the digital computer **22**, each frame will be different to produce an animation sequence.

MODULATION OSCILLATORS (FREQUENCY SYNTHESIZER AND FUNCTION GENERATOR)

Referring to FIGS. **6** and **7**, there are shown the frequency synthesizer **32** and function generator **34** of this invention, the purposes of which are to generate modulation signals in response to information received from the digital computer **22** through the interface units for use in producing depth, vertical and horizontal modulations by feeding these signals to the inputs **107**, **108** and **109** of the analog portion **26**. With these slgnals each raster section can be formed in a variety of ways to produce a variety of animation effects. For example, vertical modulation can be used to bend the raster lines, horizontal modulation to vary the rate at which a raster line is drawn producing horizontal distortions, and depth modulation to create depth distortions similar to foreshortening effects obtained optically with wide angle lenses.

Many of the major components of the networks of FIGS. **7** and **8** are discloed in detail in copending U.S. Pat. application Ser. No. 72,642, filed Sept. 16, 1970, now Pat. No. 3,609,917, Frequency Selector and Synthesizer, which will be referenced where appropriate.

The frequency synthesizer **32** generates coherent digital signals of selected frequencies and includes a voltage controlled oscillator (VCO) and master synthesizer **400**, the details of which are shown in FIGS. **2** and **2A** of the referenced application, Ser. No. 72,642. A minor difference between the synthesizer **400** and the one disclosed in the referenced application is that its master oscillator has a frequency of 9.6 megahertz rather than 10 megahertz so as to be easily divisible to produce the 1.2 megahertz signal. As previously explained, the 1.2 megahertz signal is fed through the conductor **111** to the input of the sync generator **112** of FIG. **4**, for generating the horizontal and vertical reset signals. With this difference in master oscillator frequencies, the frequencies generated at the output of the synthesizer **400** are also reduced by factors of 0.96 from the output frequencies of the network of FIG. **2** and **2A** of the referenced application. These output frequencies, which need not be described here, since they are clearly desribed in the referenced application, are fed into a digital frequency selcctor **401** for producing at its output a digital synthesized signal which appears on an output conductor **402**. By simply paralleling digital frequency selectors of the type **401**, a plurality of coherent synthesized digital signals can be produced. For example, in this described embodiment, three such signals are necessary for vertical, horizontal and depth modulations and therefore three digital frequency selectors of the type **401** would be required. Since they are identical only one need be described.

The frequency of the output signal from the digital frequency selector **401** is determined by signals from a series of four-to-ten line decoders **404**, **405**, **406**, **407**, **408**, **409** and **410**. The frequency selector **401** is basically the same type as disclosed in FIG. **4** of the referenced application, except that the switches **501** through **507** of that FIG. **4** used to select the synthesized frequency desired are replaced by the decoders **404** through **410** and a shift register **411**. The shift register **411** has an input conductor **412** connected to a control mode switch **414** having an internal position **415** and an external position **416**. In either mode setting the shift register **411** is loaded with digital parameter information which is fed through suitable conductors to the decoders **404** throuh **410**. Each of these decoders has 10 outputs representing the number 0 through 9, one of which is activated in accordance with the binary coded decimal (BCD) number at its input. The signals at the outputs of the decoders **404** through **410** perform the same function as the swtches **501** through **507** of FIG. **4** of the referenced application to gate the appropriate ones of the output frequencies from the synthesizer **400** to a series of frequency adders such as the adders **530**, **540** and **544** of FIGS. **4** and **5** of the referenced application to produce at the output of the selector **401** a synthesized signal of the selected frequency.

With the mode switch **414** in its external position, digital parameter information defining the frequency of the synthesized signal is fed serially from the output **316** of an interface uiit of the type **285** to an inut of the shift register **411**. Simultaneously with the transfer of the parameter information, the clock pulses on the output conductor **317** of the same interface unit are fed to an input of the shift register **411** to load the shift register with the parameter information. After the shift register **411** is loaded, the digital parameter information in BCD form is fed to the decoders **404** through **410** whih decode the information and feed it to inputs of the selector **401** for defining the frequency of the synthesized signal at its output **402**. Hence, with the mode switch **414** in its external position, the frequency of the synthesized signal is controlled by the digital computer **22**.

With the switch **414** in the internal position, the frequency of the synthesized signal is selected by setting a series of BCD, seven-place, thumb-wheel switches **420**, **421**, **422**, **423**, **424**, **425** and **426** to the frequency desired. With the switch **414** in this mode setting, the digital comuter **22** has no effect in selecting the frequency of the synthesized signal from the selector **401**. The frequency is controlled exclusively by the settings of the BCD switches **420** through **426** which feed information in binary coded decimal form directly through the shift register **411** to the decoders **404** through **410**, the outputs of which define the frequency of the synthesized signal as heretofore described.

Having defined the frequencies of the modulation oscillators, it is necessary to define their phases, amplitudes, waveform,, and synchronization modes. This is accomplished in the function generator **34** of which there is one for each modulation signal required. The synthesized digital output signal from the digital frequency selector **401** of the frequency synthesizer **32** is fed through the conductor **402** to an input of an up-

down counter **440** which counts the pulses of the synthesized digital signal alternately upward and downward between prescribed limits producing binary weighted outputs which are fed to the input of a digital to analog converter **442.** The converter **442** produces at an output conductor **444** a stairstep triangular waveform of a frequency depending on the frequency of the signal from the frequency synthesizer **32** and the upper and lower limit settings of the up-down counter **440.** For example, if the up-down counter **440** is set to count alternately up and down between counts of zero and 50, the frequency of the triangular waveform output from the converter **442** would be 1/100 of the frequency of the synthesized signal. If the up-down counter **450** is set to count alternately up and down between counts of zero and 500, the frequency of the triangular waveform output from the converter **442** is 1/1,000 of the frequency of the synthesized signal from the frequency synthesizer **32.** The up-down counter **450** and digital to analog converter **442** perform generally the same function in this circuit as the up-down counter **22** and digital to analog converter **24** performs in the circuit of FIG. 7 of the above-referenced application Ser. No. 72,642.

The up-down counter **440** has a triangle/sawtooth enable input **446** which controls whether the counter **440** counts alternately up and down to produce a triangular waveform from the output conductor **444** or is reset each time it reaches an upper limit (or lower limit) to produce a sawtooth waveform at the output conductor **444.** In either case the triangle or sawtooth waveform output from the converter **442** is fed through the conductor **444,** a conductor **448** and a resistor **450** to an analog gate **452.** The wave form on the conductor **444** is also fed through a side shaper **454** to produce at its output a sinusoidal waveform which is fed through a conductor **456** and resistor **458** to an analog gate **460.** An output from the up-down counter **440** is fed through a conductor **462** to a level converter **464** to produce at its output a square waveform which is fed through a conductor **466** and a resistor **468** to an analog gate **470.** Hence, the counter **440,** converter **442,** sine shaper **454** and level converter **464** produce triangle, saw tooth, sine and square waveforms from the digital frequency signal of the frequency synthesizer **32.** It is still necessary however to select a particular one of these waveforms for each modulation signal, and to define its phase and synchronization mode.

A shift register **472** receives serial parameter information and serial clock pulses at input conductors **316** and **317,** respectively, from an interface unit of the type **285,** which serial parameter inforation defines the phase, waveform and synchronization mode of a particular modulation signal. The phase data information is transferred from the shift register **472** through suitable conductors to a phase angle translator **474,** while the data defining the waveform and synchronization mode is transferred through suitable conductors to a function control circuit **476.** The function control circuit **476** has an input connected by a conductor **478** and the conductors **333, 334, 116** and **114** to the horizontal reset output of the sync generator **112** (FIG. 4), and an input connected by a conductor **480** to the output conductor **337** of the interface unit of the type **288** for receiving the section change signals.

The function of the phase angle translator **474** and shift register **472** are to set the phase of the modulation waveform. To explain how this is done, suppose that the counter **440** is made to start from a count of zero and count alternately between counts of zero and 50 so that a complete cycle is equivalent to 100 counts. For purposes of establishing a phase for the waveform, a single cycle is divided into 100 counts with each count equivalent to a particular phase. The phase angle translaor **474** receives the phase data from the shift register **472** and converts it to binary weighted outputs which are fed to the up-down counter **440** to preset its count to a prescribed number, and also sends a signal either through a conductor **482,** causing the counter **440** to count up, or a conductor **484,** causing the counter **440** to count down from the prescribed number, thereby setting the phase of the waveforms produced therefrom. The phase data in the shift register **472** has a binary weight of some number between zero and 100, which data is fed to the phase angle translator **474.** If the data represents a number between zero and 50, then the phase angle translator **474** transfers that data directly to the counter **440** together with a signal on the conductor **482** causing the counter to count up from that number. However, if the phase data in the shift register **472** represents a count of between 50 and 100, the output of the shift register would have no meaning to the counter **440** since it never reaches counts of over 50. Therefore, the phase angle translator **474** translates data representing numbers between 50 and 100 to numbers between 0 and 50 which do have meaning to the counter **440.** For example, if the data from the shift register **472** represetts the number **60,** to designate a corresponding phase the translator **474** translates the number 60 to the number 40 and transfers data representing the number 40 to the counter **440** together with a signal on the conductor **484** causing the counter **440** to count down. Hence, the purpose of the phase angle translator **474** is to convert phase data from the shift register **472** to data that has meaning to the counter **440** for establishing the phase of its output waveform.

If the counter **440** is in its divide-by-1,000 mode so that it counts alternately between zero and 500, a complete cycle would have 1,000 counts and the phase data fed through the conductor **316** to the shift register **472** would represent some count between zero and 1,000 to define the phase of the output waveform from the counter **440.**

The fuction control circuit **476** has an output conductor **490** which carries an enable signal to the gate input of the analog gate **452,** to gate the triangle or sawtooth waveform, as the case may be, from the output of the converter **442** to the input of a summation amplifier **491.** The function control circuit **476** has another output conductor **493** which carries an enable signal to the gate input of the analog gate **460** for gating the sinusoidal waveform from the sine shaper **454** to the input of the summation amplifier **491.** The function control circuit **476** has another output cnnductor **494** which carries an enable signal to the gate input to the analog gate **470** to gate the square waveform from the output of the level converter **464** to the input of the summation amplifier **491.** The parameter data in the shift register **472** defining the waveform of a particular modulation signal is fed to the function control circuit **476** which sends a signal through the conductor **490, 493** or **494** to gate the selected waveform signal through the summation amplifier **491** to one input of a

multiplier **496**. The multiplier **496** has another input connected by a conductor **497** to the output conductor **329** of a interface unit of the type **287** for receiving information defining the amplitude of the selected waveform.

To produce certain animation effects it is desirable to phase-lock the modulation signals with the generation of a particular raster section or with the generation of each raster line of a particular raster section. The latter synchronization mode might be desirable, for example, in producing a bend in a raster section where each line of the raster must be bent at precisely the same place. It might also be desirable to have no phase lock, allowing the modulation signal to free run. To provide these synchronization modes, the parameter data in the shift register **472** defining the synchronization mode is fed to the function control circuit **476** which, in accordance with the synchronization mode selected, transmits either the horizontal reset signals at its input conductor **478**, the section change signals at its input conductor **480**, or neither if in the free run mode, through an output conductor **498** to an input of the up-down counter **440**. At each pulse on the input conductor **498**, the counter **440** is reset to begin counting from a phase condition defined by the phase data from the phase angle translator **474**. The function control circuit **476** also sends a signal through a conductor **499** to the counter **440** to time the loading of the phase data from the translator **474** into the counter **440**.

Hence, in this manner, a modulation signal of a defined frequency, phase, waveform, amplitude and synchronization mode is produced at the output of the multiplier **496** and fed through a conductor **500** to an appropriate modulation input to the analog portion **26** such as the input **107**, **108** or **109** for use in producing depth, vertical or horizontal animation. Since three modulation signals are needed in this embodiment, three function generators of the type described are required.

INTENSITY COMPENSATION

Referring to FIGS. **4** and **4A**, there is shown an intensity compensation network **520** the details of which are disclosed in copending U.S. Patent application Ser. No. 74,662, filed Sept. 23, 1970, entitled Beam Intensity Compensator, having an input conductor **521** connected from an intensity input **522**. The input **522** receives analog information from an interface unit of the type **287** defining the beam intensities of the scanning devices of the system on which the image is produced which devices include the scan convertors of the color network **67**, the X-Y monitors **79, 81** and **83** of FIG. **3**, and the overlap network **56** of FIG. **1**. The network **520** also has an input conductor **523** connected from the vertical size input **100** to carry vertical size information, an input conductor **524** connected from the horizontal size input **97** to carry horizontal size information, an input conductor **525** connected to the output of the summation amplifier **230** to carry depth information, an input conductor **526** connected from the vertical modulation input **108** to carry vertical modulation signals, and an input conductor **527** connected from the horizontal modulation input **109** to carry horizontal modulation signals. The purpose of the intensity compensation network **520** is to compensate the beam intensities of the display devices for variations in size of the image and scan velocity of the spot as the beam travels across the screen of the device. The intensity compensation signal for the monitored display is fed through a conductor **530** to modulate the video signals to the scan converters or X-Y monitors, and the intensity compensation signal for the overlap network is fed through a conductor **531** to modulate the video signal to the overlap network **56**.

OPERATION

To describe the operation of the system, it is best to consider an example of how a particular animation sequence is generated by referring to FIGS. **8** through **12**. Suppose it is desired to produce an animated sequence of a cartoon caricature of a man walking with the wind blowing his hat off. The character includes a right arm **601**, a right leg **602**, a hat **603**, a head and body **604**, a left leg **605**, and a left arm **606**. As previously described, an animation sequence is composed of a finite number of frames, the frequency of which depends upon whether the sequence is to be filmed, recorded on video tape, or displayed on a TV monitor. If the sequence is to be filmed, the frame rate should be 24 frames per second to be compatible with movie film rates; if the image is to be displayed on a TV monitor or recorded on video tape for use in the United States, the frame rate should be 30 frames per second for compatibility with the US TV scan rate. To produce the sequence, it is first necessary to establish image parameters for initial and final frames of the sequence, and the manner in which the image is to move between initial and final frames, requiring among other things the selection of the number of frames in the sequence, the number of raster sections on which the image is to be displayed, and the fairing functions defining the rates of parameter change throughout the sequence. All of these variables are in the control of the operator.

Suppose in this illustration that during the sequence the man takes one half step from an initial position shown in FIG. **9** to a final position shown in FIG. **10**, and that as he takes the one half step, his hat is blown off his head as shown in FIG. **10**. Further suppose that his arms and legs move from an initial position to a final position as shown.

Because there are a total of six different parts **601** through **606** of the figure moving relative to one another during the sequence, each of these parts are produced on a separate raster section; the right arm **601** on a raster section **610**, the right leg **602** on a raster section **611**, the hat **603** on a raster section **612**, the head and body **604** on a raster section **613**, the left leg **605** on a raster section **614**, and the left arm **606** on a raster section **615**. Therefore, controls on the director **20** are set to select a total of six raster sections and to establish the number of raster lines in each section.

Because the overlap network **56** of FIG. **1** blanks the last generated overlapping information, the parts of the figures should be generated from foreground to background. Hence, the raster sections should be generated in the following order: right arm section **610**, right leg section **611**, hat section **612**, head and body section **613**, left leg section **614**, and left arm section **615**. These various body parts are drawn from top to bottom on a piece of artwork **618** and displayed such as on the light box **45** of FIG. **1**. A video camera such as the camera **42** of FIG. **1** is made to scan the artwork **618** from top to bottom at rates determined by the horizontal and

vertical reset pulses from the sync generator **112** of FIG. **1.**

At this point it should be mentioned that it is not absolutely necessary that the artwork **618** be arranged so that the camera **42** scans from top to bottom. With the appropriate circuitry, the camera can be made to scan the various parts of the artwork in any desired sequence to accommodate the overlap network **56.** In any case, for the purposes of this example, it will be assumed that the artwork is drawn in the sequence shown and that the camera scans from top to bottom.

Appropriate controls of the director **20** are set to feed digital parameter information to the digital computer **22** which in turn is fed to the switcher **52** as the sequence is generated to switch the video information from the camera **42** to the input of the grey level encoder **54** which produces at its output signals representing the artwork **618** in discrete shades of grey. The output signals from the grey level encoder **54** are fed to the video gate **58** together with signals from the output of the overlap network **56** which prevent overlapping on the part of the image where one part is positioned behind another, to produce on the output conductor **60** from the video gate **58** video signals representing the artwork in discrete shades of grey for use in producing the animation sequence.

The operator must also select the number of frames in the sequence. This, of course, depends on how fast the figure is to walk, but assume for purposes of this example that he is to walk at a rate of half a step per second. With TV rates of 30 frames per second, 30 frames are selected for the sequence by setting the controls on the director **20.** If the sequence is to be filmed, 24 frames are selected. By adjusting the analog input **270** and channel select **272** controls of the director **20,** and by observing the monitor **73** of FIG. **2,** the operator varies all of the parameters for each raster section of the image necessary to set up the initial frame of the sequence with the image of FIG. **9.** Hence, for each raster section **610** through **615,** digital signals are sent sequentially to the digital computer **22** representing X position, Y position, horizontal size, vertical size, section depth, and intensity, as well as signals defining the number of lines in each raster section and the red, blue and green color components of each color in each frame. Additionally, the arms, legs, and hat must be made to rotate about given points between initial and final frames, the hat being made to rotate about a point **620,** the legs about a point **621** located at the hips, and the arms about a point **622** located at the shoulders. In this illustration the head and body section **613** remains erect throughout the sequence although, of course, it could be made to rotate if desired. Therefore, for each raster section, digital signals are sent to the digital computer **22** from the director **20** defining the cosine and sine of the angles of rotation, and the vertical and horizontal axes of rotation.

Certain other parameters must also be defined. It will be noted that in the initial frame the left arm has a bend at the elbow and the left leg has a bend at the knee, whereas in the final frame the right arm has a bend at the elbow and the right leg has a bend at the knee. Vertical moduation signals are used to produce these bends, which signals are generated by the frequency synthesizer **32** and function generator **34** from parameter information supplied them from the digital computer **22.** Each of these modulation signals has five parameters that must be defined: frequency, phase, waveform, amplitude and synchronization mode. Since elbow and knee bends are fairly sharp, a triangular waveform is selected as more suitable than a sinusoidal or square waveform. Also, these bends require that each raster line of a raster section on which one of the arms or legs is produced be bent the same amount and in exactly the same place. Therefore, synchronization mode should be selected such that the generation of the modulation signals for each raster section is synchronized with the generation of each raster line in the section, i.e., with the horizontal reset pulses. Hence, the controls of the director **20** are set to select a triangular waveform, synchronization on the horizontal reset signals, and the appropriate frequency, phase and amplitude for the vertical modulation signal for each of the raster sections **610, 611, 614** and **615** for the initial frame of the sequence.

In addition to the individual section parameters, the controls of the director **20** are set to establish the parameters for the overall image of the initial frame, namely, overall X position, overall Y position and overall depth.

As all of this parameter information is sent to and stored in the digital computer **22,** the digital computer **22** is programmed to feed the parameter information for each raster section of the initial frame to the various interface units, as heretofore described, beginning with the information defining the raster section **610** and followed by the information for the raster section **611, 612, 613, 614** and **615,** in that order. The channel address counter **302** sequentially directs each piece of digital parameter information to the appropriate interface unit as heretofore described. Hence, information defining raster section **610** is first sequentially loaded into the interface units which information is transferred from these units to the appropriate input of the other networks of the system in response to the vertical reset signal from the sync generator **112,** at which time the digital parameter information for the next section **611** is loaded sequentially into the interface units and transferred to appropriate inputs of the system in response to the section change signal at the output of the section length counter **331** (FIG. **5**), and so on for the section **612, 613, 614** and **615** to generate the initial frame of the sequence. The sections **610** to **615** are, of course, drawn continuously, but two or three raster lines are blanked at the beginning of each section. The blanking is produced by signals generated by the blanking network **338** in response to the section change signals from the section length counter **331,** the horizontal reset pulses, and the vertical reset pulses. The section change signals in turn are generated in response to information stored in the digital computer **22** defining the number of lines in each raster section. These blanking signals from the blanking generator **338** are fed through the conductor **345** to blank the beam of the scan converter of the color network **67** between sections.

Upon transfer of each block of parameter information defining each raster section from the interface units, digital parameter information is fed from the output of the interface units of the type **285** to the input of the shift register **411** of the frequency synthesizer **32** to define the frequency of the vertical modulation signal, and to the inputs of the shift register **472** of the function generator **34** for defining the phase, waveform

and synchronization mode of the vertical modulation signal. Also for each raster section, an analog parameter signal is fed from the output of an interface unit of the type **287** through the conductor **497** to an input of the multiplier **496** of the function generator **34** defining the amplitude of the modulation signal. The result is to produce at the output conductor **500** of the function generator **34** a series of modulation signals of frequencies, phases, waveforms, amplitudes and synchronization modes that produce the bends in the raster sections **610, 611, 614** and **615** of FIG. **12.** The modulation signal for each raster section is fed to the vertical modulation input **108** of the analog portion **26.**

Digital parameter information is fed from interface units of the type **286** to perform various network control functions such as the setting of the switch **52** to switch the video information from the camera **42** through to the grey level encoder **54.**

Analog parameter signals are fed from the outputs of the interface units of the type **287** to the overall X position input **95,** section X position input **96,** section horizontal size input **97,** section horizontal axis of rotation input **98,** section vertical axis of rotation input **99,** raster vertical size input **100,** raster Y position input **101,** overall Y position input **102,** section depth input **103,** overall depth input **104,** cosine R input **105,** sine R input **106,** and intensity input **522** of the analog portion **26.** Where a color display or video tape of the animation sequence is to be produced, analog voltages from other units of the type **287** are fed to the color network **67** of FIG. **2** to define the red, blue and green color components for each discrete grey shade. Where the sequence is to be recorded on color film, these signals are fed to the RGB color encoder **77** of FIG. **3.**

As the analog parameter signals defining each raster section are fed to the inputs of the analog portion **26** sequentially by raster section, the integrators **118** and **144** of the analog portion **26** are generating horizontal and vertical ramp functions synchronized with the horizontal and vertical reset pulses from the sync generator **112.** Since the video camera **42** also scans in synchronization with the horizontal and vertical reset pulses from the sync generator **112,** the generation of the horizontal and vertical ramp functions from the integrators **118** and **144** is synchronized with the scan of the video camera **42** scanning the artwork **618.** The horizontal and vertical ramp functions are combined with the analog parameter signals at the input of the analog portion **26** as heretofore described producing, at the output conductors **92** and **93,** X and Y coordinate output signals sequentially representing the raster sections of the initial frame.

These X and Y coordinate signals are fed to an input of the overlap network **56** together with the video signals from the output of the grey level encoder **54** to produce the overlap compensated video signal on the conductor **60** representing the artwork in discrete shades of grey. The X and Y coordinate output signals from the analog portion **26** and the video signals on the conductor **60** can be fed to the color network **67** to produce a color display of the initial frame on the color monitor **73.** The operator in setting up the initial frame can observe the effects of varying the controls of the director **20** on the color monitor **73** until he is satisfied with the initial frame image.

After he is satisfied with the initial frame, the operator initiates a control signal on the director **20** to the digital computer **22** to store the initial frame parameter information in the computer **22.** Having done this, he sets up the parameters for the final frame in exactly the same manner with the networks sequentially generating each section of the final frame of the sequence as the operator varies the controls of the director **20** until he is satisfied with the final frame parameter.

In most cases, the parameters of the final frame are different from those of the initial frame. For example, in this illustration the X and Y position and angle of rotation parameters of the hat **603,** and therefore the section **612** are different. The angles of rotation of the arms about the shoulders and hence the sections **610** and **615** are different, as are the angles of rotation of the legs about the hips and hence the sections **611** and **614;** also, since the left arm and left leg go from bent to straight positions, and the right arm and right leg go from straight to bent positions, the amplitudes of the vertical modulation signals for the sections **610, 611, 614** and **615** are different.

Having established the initial and final frame parameters for the sequence, appropriate fairing functions must be selected to define the rates of change for these parameters throughout the sequence. Fairing functions can be selected that vary linearly, exponentially, or in some other manner. To put it in terms of this illustration, the hat **620** can be made to leave his head very suddenly and then blow away at a constant rate or perhaps at a decreasing rate; the arms can be made to bend and straighten at the elbows in a constant manner throughout the sequence, or perhaps slowly at first, gradually increasing, and then slowly at the end of the sequence. The same is true with respect to the straightening and bending of the knees as well as the rates of rotation of the hat and each arm and leg throughout the sequence. For purposes of this example, assume that the hat is to blow off suddenly and then proceed at a constant rate, and that further it is to rotate from the position of the initial frame to the position of the final frame at a constant rate. Therefore, linear fairing functions are selected to define the parameter changes between initial and final frames of the raster section **612.** Also assume that the bends in the knees and elbows are to change at a constant rate throughout the sequence, so that a linear fairing function is selected to define the amplitude changes of the vertical modulation signals throughout the sequence. Assume, however, that the rotation of each arm about its shoulder point **622** and each leg about its hip point **621** is to begin slowly, gradually increasing at the middle of the sequence, and then gradually slowing to the end of the sequence. Appropriate fairing functions are selected to vary the angles of rotation of the raster sections **610, 611, 614** and **615** accordingly. In selecting these fairing functions, appropriate command signals are sent from the director **20** to the digital computer **22** which is programmed to make parameter calculations in accordance with these selected functions.

The digital computer **22** now has all the information for defining the initial and final frames of the sequence as well as the fairing function information as to how the image parameters should vary throughout the sequence. With the digital computer **22** programmed to calculate the section parameters for each frame between initial and final frames of the sequence in accordance with the fairing functions selected upon appropriate command from the director **20,** the digital com-

puter 22 goes into its record mode and automatically computes this information and records it on the digital recording medium such as magnetic tape 36 and/or disc 38.

With the digital parameter information defining the entire animation sequence recorded, upon appropriate command from the director 20 the control network is placed in the playback mode to play the digital parameter information recorded on the tape or disc back to the digital computer 22 from which it is fed section by section and frame by frame as heretofore described to the interface units. From there it is fed to other inputs of the system to produce a color display or video tape of the animation sequence. Also the video signals on the conductor 60 can be fed to the RGB color encoder 77, and the X and Y coordinate output signals from the analog portion 26 fed to the X-Y monitors 79, 81 and 83 (FIG. 3) to produce a color film of the sequence.

With this sequence completed, the operator may wish to create a second sequence with the cartoon character of FIGS. 9 and 10 taking the second half step. To do this, an initial frame is set up for the second sequence the same as the final frame of the first sequence, and a final frame is set up for the second sequence the same as the initial frame of the first sequence. The operation heretofore described is then repeated to produce the second sequence so that now a sequence has been produced of the character taking a full step. By appropriately rerecording the digital parameter data for this sequence on the digital magnetic tape 36, a sequence of any length can be produced of the character walking.

This example is only meant to illustrate the basic operating principles of the system and by no means describes the multitude of animation variations that can be achieved on this system. Indeed, by appropriately selecting scene length and parameter variations such as fairing functions and modulation signals, an unlimited variety of animation effects can ve achieved. As still a further illustration of the versatility of this system, it should be noted that once the parameters defining the raster sections, such as the raster sections 610 through 615, have been established for a given animation sequence, any figure can be produced thereon and caused to animate in exactly the same manner by simply changing the artwork 618. For example, if the artwork 618 where changed to show the parts of a rabbit, the rabbit would be produced on the raster sections 610 through 615 and caused to move in the animation sequence just as the characters of FIGS. 9 and 10. In fact, it may be desirable in producing certain effects to have no artwork at all and instead show the raster sections themselves which in the above exmaple would produce an animation sequence of the rasters shown in FIGS. 11 and 12.

Various changes and modifications may be made within the invention as will be readily apparent to those skilled in the art. Such changes and modifications are within the scope and teaching of this invention as defined by the claims appended hereto.

What is claimed is:

1. A method of producing an animation sequence of a subject from a single still view of the subject comprising the steps of generating video signals representing each part of the subject as selectively divided into one or more parts; reproducing each of said parts of the subject on a separate raster section generated from parameter signals defining its size, shape, position, and structure; the generation of each raster section being synchronized with the generation of the video signals representing the part of the subject produced thereon, establishing a series of digital signals representing the parameters for each raster section over a given time interval, which digital signals are selectively varying over said time interval, and selectively varying the parameter signals over said time interval in response to the digital signals to produce changes in selected ones of the raster sections, thereby producing corresponding changes in the parts of the subject reproduced thereon.

2. The method of claim 1 further comprising the step of recording the sequence.

3. The method of claim 1 further comprising the step of displaying the parts of the image as reproduced on the raster sections.

4. The method of claim 1 further comprising the step of generating video signals representing background information in synchronization with the production of the animation sequence of the subject.

5. A method of producing an animation sequence of a subject from a single still view still the subject comprising the steps of scanning each part of the subject as selectively divided into one or more parts to produce video signals representing each part, generating parameter input signals defining the size, shape, position and structure of a raster section for each of said parts of the subject, combining the parameter input signals to generate, in synchronization with the generation of the video signals representing each part of the subject, time varying coordinate signals defining a raster section, modulating the intensity of the electron beam of an electron beam device with the video signals representing each part of the subject while simultaneously directing the scan pattern of the electron beam with the coordinate signals produced in synchronization therewith to reproduce each part of the subject on a separate raster section, establishing a series of digital signals defining the parameters for each raster section over a given time interval, which digital signals are selectively varying over said time interval, and selectively varying the parameter input signals over said time interval in response to the digital signals, thereby producing corresponding changes in the scanning patterns of the electron beam, the raster sections produced thereby and the parts of the subject produced thereon.

6. The method of claim 5 wherein the position parameters include parameters that define the angles of rotation of the raster sections, and the method further comprising the step of varying over time the angle of rotation parameters for selected ones of the rasters to vary the angles of rotation of these rasters with respect to reference axes.

7. The method of claim 5 wherein one of the scanning pattern changes produces changes in the degree of bend in the raster lines of selected ones of the raster sections.

8. The method of claim 5 including the step of generating in synchronization with the generation of the video signals horizontal and vertical sweep signals of selected slopes as part of the parameter input signals.

9. The method of claim 5 further comprising the steps of generating modulation signals, and selectively modulating the sweep signals with the modulation signals.

10. The method of claim 5 further comprising the step of generating video signals representing background information for the animation sequence and combining the background information video signals with the video signals representing each part of the subject to produce an animation sequence of the subject with background.

11. The method of claim 10 further comprising the step of blanking parts of the display positioned behind other parts of the display.

12. A method of producing an animation sequence of an image, the sequence divided into frames between initial and final frames, the method comprising the steps of generating first sets of digital signals representing scan pattern parameters for the initial frame of the sequence, generating second sets of digital signals representing scan pattern parameters for the final frame of the sequence, generating further sets of digital signals using the initial and final digital parameter signals as references representing scan pattern parameters for each frame therebetween in accordance with selected functions defining the patterns of parameter change from frame to frame throughout the sequence, each set of digital signals in each frame representing a distinct scan pattern, converting the digital signals in each set of digital signals to analog signals, generating from each first set of analog signals a distinct scan pattern, the scan patterns from the first sets representing the image of the initial frame, and generating a distinct scan pattern from each further set of analog parameter signals for each subsequent frame through the final frame of the sequence to produce a series of images.

13. The method of claim 12 further comprising the step of reproducing the parts of a subject divided into a selected number of parts on the scan patterns in each frame of the sequence.

14. The method of claim 13 further comprising the steps of causing the beam of a video camera to scan each part of the subject in synchronization with the generation of a scan pattern to produce video information representing each part of the subject, there being as many scan patterns generated per frame as there are parts of the subject, and producing an animated sequence of the subject from the scan patterns and video signals.

15. The method of claim 14 further comprising the steps of producing a recording of the sequence.

16. The method of claim 12 further comprising the steps of recording the digital signals representing the scan pattern parameters, and playing the digital recording back to produce the analog signals.

17. The method of claim 12 including the steps of loading the digital signals in each set sequentially into buffer units, and transferring the digital signals in each set simultaneously from the buffer units to generate a scan pattern.

18. A method of generating an image comprising the steps of generating horizontal and vertical sweep signals representing straight-line raster scans, establishing sets of digital data, the digital data in each set defining parameters representing the size, shape, position and structure of a raster section, converting the digital data in each set to analog parameter signals, combining the analog parameter signals in each set and the sweep signals in a selected manner and sequence to produce time varying coordinate signals representing a series of raster sections, generating modulation signals, combining the modulation signals with selected ones of the analog parameter signals, the digital signals defining selected raster sections including signals defining the frequency phase, amplitude, and waveform of the modulation signals.

19. The method of claim 18 further comprising the step of applying the coordinate signals to the beam deflection inputs of a cathode ray tube display device to produce a display of the image.

20. The method of claim 19 further comprising the steps of generating video signals representing each part of a subject divided into a selected number of parts in synchronization with the generation of a raster section, and modulating the intensity of the cathode ray tube beam with the video signals to produce a display of the subject, whereby the size, shape and position of each part of the displayed subject are determined by the size, shape and position of the raster section on which it is reproduced.

21. The method of claim 20 further comprising the step of compensating the beam intensity of the cathode ray tube for variations in size of the image and velocity of the spot as the beam scans.

22. The method of claim 18 further comprising the step of combining a modulation signal of a selected frequency, phase, amplitude and waveform with the vertical sweep signal to bend the lines of selected raster sections.

23. The method of claim 18 further comprising the step of combining a modulation signal of a selected frequency, phase, amplitude and waveform with the horizontal sweep signal to vary the rate at which the raster lines of particular raster sections are drawn.

24. The method of claim 18 further comprising the step of combining a modulation signal of a selected frequency, phase, amplitude and waveform with the analog parameter signals defining the depth of particular raster sections.

25. The method of claim 18 further comprising the step of synchronizing the generation of a modulation signal with the generation of each line of a selected raster section.

26. The method of claim 18 wherein the analog parameter signals include signals representing the sines and cosines of angles through which selected raster sections are to be rotated with respect to a reference axis, and further comprising the step of combining combinations of other analog parameter signals with the sine and cosine parameter signals to rotate the selected raster sections.

27. The method of claim 26 wherein some of the combinations of other analog parameter signals combined with the sine and cosine parameter signals are produced by combining modulation signals with selected ones of the analog parameter signals.

28. A computer animation system for generating an animation sequence comprising a digital computer means, means for feeding digital data to the digital computer means defining certain parameters of an image for an initial frame of the sequence, means for feeding digital data to the digital computer means defining certain parameters of the image for a final frame of the sequence, means associated with the digital computer means for automatically calculating, upon command, the digital data defining certain parameters of the image for each frame between initial and final frames in accordance with selected patterns of parame-

ter change throughout the sequence, means for converting the digital data to analog signals, and means for combining the analog signals to produce signals representing the animation sequence.

29. The system of claim **28** including digital recording means, means for recording the digital data defining the parameters of the image for each frame of the sequence on the digital recording means, and means to play back the digital data on the digital recording means.

30. The system of claim **28** including a subject, means for producing video signals representing the subject, and means responsive to the video signals and signals representing the animation sequence to produce an animation sequence of the subject.

31. The system of claim **30** including means responsive to the video signals and signals representing the animation sequence to produce a color representation of the animation sequence of the subject.

33. The system of claim **30** including means for blanking parts of the subject positioned other parts of the subject.

33. A system for generating time varying coordinate signals for producing an animation sequence of an image on a display device, film, or video tape, the system comprising an analog network means having analog inputs and outputs, means for generating horizontal and vertical sweep signals representing straight line raster scans, circuit means associated with the analog network means for generating time varying coordinate signals representing a particular raster section at its outputs from a given set of parameter signals and the sweep signals at its inputs, the parameter signals defining the size, shape, position and structure of the raster section, digital input means for storing and transferring sets of digital data defining the parameters of each raster section to be generated, means for feeding digital data to the digital input means defining each parameter of each raster section to be generated, means for feeding the sets of digital data relating to the parameters of each raster section to be generated from the digital input means in a prescribed sequence, means for converting the sets of digital data from the digital input means to sets of analog parameter signals, means for feeding the sets of analog parameter signals and the sweep signals to the appropriate inputs of the analog network means to produce the time varying coordinate signals representing a series of raster sections, means to generate video signals representing each part of a subject divided into a selected number of parts, the generation of the video signals for each part of the subject being synchronized with the generation of the time varying coordinate signals representing a raster section, and means responsive to the video and coordinate signals for producing a display of the animation sequence of the subject.

34. The system of claim **33** wherein the sequence is comprised of frames, the video signals representing each part of the subject being generated during each frame.

35. The system of claim **33** including means for generating signals defining the red, blue and green color components for colors assigned to each part of the subject, and means responsive to the video signals, coordinate signals, and color component signals to produce a color representation of the animated subject.

36. The system of claim **33** including means defining the number of lines in each raster section.

37. The system of claim **33** including means for rotating each raster section about a selected axis of rotation.

38. The system of claim **37** wherein the analog parameter input signals defining each raster section include signals defining the size and axis of rotation of the raster section, and including means for automatically compensating the axis of rotation for variations in size of the raster section.

39. The system of claim **38** wherein the size parameter signals are multiplied by the axis of rotation parameter signals.

40. The system of claim **33** including means for feeding the digital data within each set of digital data to the conversion means in a prescribed sequence, and means to simultaneously transfer the digital data in each set of digital data to the inputs of the analog network means.

41. A system for generating an animation sequence of an image composed of one or more raster sections, each raster section being defined in terms of size, shape, position and structure by analog parameter signals, the sequence divided into frames between initial and final frames, the system comprising analog network means having coordinate outputs and parameter inputs, means associated with the analog network means for generating time varying coordinate signals at its outputs representing a raster section of a size, shape, position and structure defined from a set of analog parameter signals at its input, digital computer means, means for feeding digital data to the digital computer means defining the parameters of the raster sections for the initial frame of the sequence, means for feeding digital data to the digital computer means defining the parameters of the raster sections for the final frame of the sequence, means associated with the digital computer means for establishing certain parameters of the raster sections between initial and final frames, means for generating as many sets of digital signals as there are raster sections composing the image for each frame, each set of digital signals defining the parameters of a raster section, means for loading the digital signals in each set in timed sequence into a series of interface units beginning with the set defining the first raster section to be generated in the first frame and continuing in timed sequence through the set defining the last raster section to be generated in the last frame, means for simultaneously initiating the transfer of the digital signals from the interface units after the last of the series of interface units is loaded with one set of signals, means for loading the digital signals of the next set into the interface units as soon as the prior set is transferred therefrom, means for converting the digital signals from the interface units to analog signals, and means for applying the analog signals to the inputs of the analog network means to produce time varying coordinate signals at its outputs sequentially representing the raster sections of the image for each frame throughout the sequence.

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